

The University of Chicago

THE EFFECT OF VARYING LEVELS
OF INTAKE ON ABSORPTION AND
METABOLISM OF FAT IN
YOUNG CHILDREN

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS
AND HOUSEHOLD ADMINISTRATION

1936

By

MARTHA ELLEN DAVIS

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INTRODUCTION

The original data presented within are specifically concerned with the role of fat in the diet of the healthy child especially as it influences fat retention and acetone excretion as well as caloric intake, energy balance, nitrogen retention and calcium excretion through the bowel.

It has been pointed out by many workers that a true evaluation of any dietary regime must take into account the total effects of the diet on the individual. The complexity of the factors involved in such a total study seems to make its accomplishment an impossibility. Because of this, the alternate plan of making single studies of different aspects of the total nutrition has been universally adopted. These latter obviously lend themselves to very limited interpretation, and simultaneous studies made on two or more nutrients for reasonably long periods of time, should yield a broader, clearer understanding of the interrelationship of these nutrients in metabolism.

Fat and the products of fat hydrolysis play an important part in the economic and nutritive welfare of any nation. Their high caloric value alone makes them important constituents of the diet. To what extent this energy is the only contribution, to what extent the metabolism of other nutrients is diverted by extremes of fat ingestion, and to what extent fat per se is necessary in maintaining an optimum state of health in the human are moot questions.

The total quantities of fats which may be ingested in a well balanced diet and the factors which limit these quantities

are not defined. There is undoubtedly a maximum level at which it can be fed without producing ketosis when the ketolytic nutrients are restricted. Whether ketogenic diets supplemented by minerals and vitamins will maintain a child in an optimum state of nutrition is not known. Such diets are a little too difficult to manage to appeal to the average mother as a regime for her normal child and it seems probable that children would not voluntarily select diets so high in fat and so low in carbohydrates.

Following the discovery of the association of the vitamins A, D, and E with fat, there has been a general tendency to disregard fat per se in the diet as an essential metabolite. Nevertheless, it has been demonstrated that certain fatty acids are required for health in the rat. Little is known of the metabolism of individual fatty acids in the human, and it does not follow a priori from the work with rats that these or other fatty acids are required by the human, especially since no specific evidences of a human deficiency, comparable to the rat syndrome have been produced. Moreover, there is a nice distinction to be made between fat deficient diets on the one hand and ketogenic diets on the other, and a desirable minimum or maximum level of fat ingestion in an ordinary mixed diet. There are in the literature on pediatrics, references to a "high fat diet" which is said to be a major factor in various types of anorexia, failure to grow, and other nutritional maladjustments. These diets appear not to be definitely or deliberately ketogenic in character, but it has been impossible to discover the ratios of fat to carbohydrates, contained in them.

A generally accepted concept for the child's dietary is that protein must be supplied in certain minimum amounts and that the remaining calories may be distributed between carbohydrate and

fats. The ratio of this distribution below the ketogenic level is apparently thought to be limited by such contributing factors as the cost, flavor, texture, and consistency of foods, as well as appetite and the vaguely defined symptoms mentioned above. A common practice is to allow 15 per cent of the total calories as protein, 35 per cent as fat, and 50 per cent as carbohydrate. A survey of the literature reveals that this percentage distribution is supported by studies on food intakes, a great number of which have been calculated from tables of average composition, rather than by definite experimental evidence of superior results from this as against other distributions.

The present study was undertaken with the thought in mind that if there were distinct advantages to the child in ingesting a given distribution of proteins, fats, and carbohydrates, such could be demonstrated by carrying out simultaneously fat, nitrogen, energy and calcium studies on diets, with varying fatty-acid to glucose ratios, some of which were extremely high but still below the generally accepted ketogenic ratio of 1.5 to one. To this end fat was fed at three distinct levels, to two children four and six years of age, in three series of balances.

These series are designated as Regular Home Diet series, wherein the fat calories averaged 39.9 and 39.3 per cent of the total; the Low Fat Diet series, wherein the per cent of the total calories as fat averaged 25.8 to 27.1; and the High Fat Diet series, wherein the fat calories averaged 62.5 to 60.7 per cent of the total intake in the two subjects. Fat, nitrogen, and calcium excretion through the bowel, and the elimination of nitrogen and acetone bodies through the urine were studied in all periods.

EXPERIMENTAL PROCEDURE

General plan.--Two children in one family, a boy six years of age and a girl four, were selected as subjects for this study. These children were known to have had excellent training in regard to dietary habits. The mother was a graduate student in the division of Foods and Nutrition at the University. She had had experience in this type of research, and understood fully the objects of the experiment as well as the technique of collecting and preserving specimens. The children lived at home, the boy went to school and the family continued its normal routines as closely as was possible when diets were being weighed and specimens collected. The family life as a whole was quite natural and normal during the entire experiment.

The physical condition of the children was satisfactory as shown by medical examination, by physical measurements, by general inspection, and by a preliminary test on two twenty-four hour specimens of urine and two stools for each child. The urine was tested for sugar, albumin, and acetone. These tests were all negative. The urine was normal in volume, color, and hydrogen ion concentration. The feces were free from undigested food or other pathological excrement.

The children had taken part in balance studies previously and already understood the duties and restrictions necessary to accurate saving of urine and feces specimens. This is a rigorous discipline for any individual and when carried out with the poise and cheerfulness shown by these subjects, it becomes a true indication of emotional and mental balance. They were at all times

interested and co-operative, but not unduly curious as to the routines set up for them. The boy's school was only two blocks from the home, and he was given permission by his teacher to go home during the morning recess or at others times when necessary. This proved to be a happier arrangement for him than the carrying of specimen bottles, and saved complications in regard to measuring his water intake.

Experimental diets.--A preliminary period of ten days was used for observations. The food was measured and the amounts recorded but no food samples were collected. The food habits, the general quality of the home diet, and the attitudes of the children toward their meals, as well as the technique by which the specimens were to be collected, were all checked. The diet during this preliminary period was well balanced in regard to known requirements. It included selections from all the food groups, that is, cereals and breads, milk, meat, eggs, cheese, sweets, fats, fruits and vegetables, with considerable variety, particularly with respect to fruits and vegetables. The observations showed that in general the minimum intake was as follows:

Food	Minimum Amount Consumed Daily
Milk	500 cc.
Orange juice	100 cc.
Fruit	50 gm.
Vegetable other than potato.	66 gm.
Vegetable, uncooked	33 gm.
Meat	25 gm.
Egg	1 egg
Cod liver oil	6 gm.

Throughout the experimental periods the minimum amounts of foodstuffs, stated above, were included daily in the diet. To provide additional protection from the possibility of a low vitamin B intake particularly during the high fat periods, 5 to 10 grams

of wheat germ were given daily in all periods. Cod liver oil, 6 grams daily, was a regular part of their program during the winter months. This was continued except as specifically stated during the low fat periods VIII and IX. The children were allowed to partake ad libitum of all foods served. No difficulty was experienced in this program except that at times they did not eat the minimum amount of meat, and occasionally they did not want the egg. Egg in the prepared foods and cheese helped to counter-balance the loss of protein and fat, through these failures. They were not especially urged to eat any foods. Only casual comments or suggestions were ever offered by the mother and these suggestions were not pressed. If the child did not respond, the matter was dropped. The children did not at any time know what variations were being made in their meals. They made little comment in regard to the flavor or content of the diet. They accepted the food during each period without protest, and with apparently little consciousness that the seasoning was varied. They did notice the difference in the flavor of the milk when it was changed suddenly from skim milk to milk and cream half-and-half. The mother's explanation that it was a new kind of milk satisfied their curiosity and no further comment was made. They continued to drink satisfactory amounts of this richer product. On previous experiments (two years before) these children had been on a routine diet with limited amounts of food all of which they were expected to consume as served. They were delighted to learn that in this balance they could have some of their favorite foods as usual and that they could eat as much as they liked of any dish served.

The daily records for food intakes and food composite preparations were kept in a systematic manner on permanent record sheets as shown by Table IV.

TABLE IV
DIETARY RECORD

Name Subject J

Date Sunday - April 26, 1931

Time	Foods	Amount in Grams			
		Served	Not Eaten	Eaten	Total Sample for Composite
8:00	Breakfast				f = 5
	milk, whole	154	0	154	30.8
	eggs				
	butter	5	1	4	.8
	orange j.	⁺²⁰ 100	0	⁺²⁰ 100	24.0
	c. l. o.			6	1.2
	yeast				
	toast				
	whole wheat				
	white toast	10	3	7	1.4
	sugar	25	9	16	3.2
	cream %				
	cereal, oatmeal	98	0	98	19.6
	bacon				
12:30	Dinner				
	milk, whole 100+	282	82	310	62.0
	butter	3	0	3	.6
	bread white	13	0	13	2.6
	whole wheat				
	hard candy	11	1	10	2.0
	gravy	10	0	10	2.0
	cake	52	9	41	8.2
	veg. raw celery	14	7	7	1.4
	veg. ckd. carrot	50	0	50	10.0
	chicken, sliced	26	0	26	5.2
	chicken liver	8	0	8	1.6
	potato mashed	62	0	62	12.4
6:00	Dinner				
	milk, whole	279	0	279	55.8
	pineapple	72	0	72	14.4
	butter	8+5	0	13	2.6
	pineapple juice	50	0	50	10.0
	bread				
	whole wheat				
	white	24	0	24	4.8
	veg. raw tomato	30	0	30	6.0
	veg. ckd.				
	lettuce	11	0	11	2.2
	egg	46	0	46	9.2
	water			60	12.0
	Total				

The collection and preparation of specimen and food samples.--Twenty-four hour specimens of food, feces and urine were collected for analysis as described below. More food was prepared each meal than was needed for serving the family. Samples were taken from the dishes from which the children were served either before or after the meal. These were placed in an air tight container or wrapped closely in waxed paper and stored in a cool place. At the end of the day these were sent to the laboratory and immediately made into composite samples. (Occasionally the entire basket had to be stored in the laboratory ice box until early morning when the composites were prepared.) Great care was exercised at all times to have all foods, such as desserts and salads, uniformly mixed and to have the sample representative of what was eaten. Small servings were the rule with seconds when desired. This helped to prevent accumulated errors due to weighing back foods left on the plates. Recipes were planned and calculated according to the cooked weight of the entire dish. These calculations were used in a preliminary daily estimation of the composition of the diet. These children did not habitually eat between meals, but if they asked for something at bedtime they were not refused. Part of the orange juice was routinely taken at bedtime with the cod liver oil. Samples of this between meal food were preserved and added to the total composite the next morning.

The water intake was measured and aliquots were added to the food samples in drying. This seemed a better procedure than requiring the use of distilled water. Each child was provided with a florence flask, equipped with a siphon. A measured amount of water was placed in these flasks twice daily or oftener when needed. These siphons added a good deal of zest to life during

the first day of the experiment, and excessive amounts were drunk, especially by Subject J. The novelty soon wore off and after the first day the flasks were accepted as routine along with the other demands of the balance.

The experimental day lasted from 7 A.M. to 7 A.M. Carmine was given at 7 A.M. on the day in which a change in diet was made. The stool containing carmine invariably appeared on the morning following administration.

The twenty-four-hour urine specimen was preserved in toluene and kept in a cool place, in ground glass stoppered bottles. The specimens were taken to the laboratory early each morning and a composite sample for each period was prepared and preserved with HCL and stored for subsequent analyses. The remainder of the fresh daily specimen was used for the daily determinations of total acetone bodies, total nitrogen, ammonia nitrogen, and creatinine.

The feces were collected directly into glass inserts which served as removable linings for enamel pails. These pails had close fitting enamel covers with half-inch flanges which set down over the edge of this inner glass container. A piece of waxed paper was stretched over the top and smoothed down over the edge of the insert, which, when eased into the pail, the waxed paper cover neatly adjusted with a thin spatula and the whole covered, proved to be a very efficient piece of equipment for preventing loss in volatile substance during transfer and storage. The procedure after this was varied slightly in the specimens collected from February 13 to March 2 from those collected April 26 to May 19. During the former periods, 25 cc. of ethyl alcohol was stirred into the moist mass immediately after defecation and the entire unit stored in a cool place until the end of the period

(about two and one-half weeks). During the latter periods, April 26 to May 19, the stools were collected as above, but were brought immediately after defecation to the laboratory. They were mixed to uniform consistence and alcohol added only to the aliquot which was put into the dryer. During all periods aliquot composites of from 20 to 25 per cent of the total stool were weighed into an evaporating dish for drying. These were heated on a water bath for one to two hours and then in a constant temperature oven at 70 to 85 degrees until constant in weight. These dried samples were used for determining moisture, ash, and calcium. Weighed fresh samples with or without alcohol as described were taken immediately after mixing for fat and nitrogen analyses. These procedures were adopted in order to avoid, as much as possible, changes in the fatty material and loss of nitrogen.

The balance periods.--The balance periods were continuous from February 13 to March 2 (18 days in all), and from April 26 to May 19 (24 days in all), inclusively. During the first 8 days (Periods I and II in the tables), the children ate their regular home diet. The 10 days following (Periods III and IV in the tables), there was enough fat added to the food, largely as butter and cream for seasoning and in the milk and cocoa drunk, to provide approximately 60 per cent of the total calories from fat. A third regular home diet period lasted from April 26 to 28 (Period V in the tables). This was followed by a 12 day period of low fat, and relatively high carbohydrate intake (Periods VI to IX in the tables). During this time little or no fat was added to the food, also the cream was removed from the milk before serving. Sweets, sweetened fruit juices and other tempting but regular constituents of their diet that were high in total carbohydrate, were set before them. Cod liver oil was discontinued for 6 days

(Periods VIII and IX), in order to further reduce the fat in the diet. This low fat intake was followed immediately by a high fat diet similar to Periods III and IV. This lasted for 9 days and is reported as Periods X to XII in the tables. There was a total of 42 days of balances for each child; 11 days on the regular home diet; 12 days on a relatively low fat diet; and 19 days on a relatively high fat diet.

The high fat Period IV was complicated for the boy, Subject T; by what appeared to be a slight cold. The girl, Subject J, developed also what appeared at first to be a slight cold, but later was diagnosed as whooping cough. These children were under the close supervision of a pediatrician at all times, and when there were definite indications that Subject J was developing whooping cough the balances were discontinued. They both suffered a mild attack of whooping cough, but were recovered and in excellent physical condition by April 26 when the study was reopened. Both were gaining weight at this time, although Subject T gained slowly. The balances were continuous with this exception. No attempt was made to accustom the subjects to a diet before the analyses were made. This was done deliberately with the thought that changes during the transition period, as well as cumulative and maximum effects on the total metabolism, should be noted.

Methods of analysis.--The methods used in the analyses in this study, except as noted below, were those described in Temporary Methods of Analysis for Agricultural Chemists, Department of Agriculture. Total nitrogen in the urine, food and feces was determined by the Gunning modification of the Kjeldahl method. Dried samples of food and feces were ashed in a muffle furnace at dull red heat, approximately 480 degrees, cooled in a dessicator and weighed. This was repeated until they were constant in weight.

Calcium was determined on the ash described above by the Shohl modification of the McCrudden method. The calcium oxalate was titrated with potassium permanganate. Calcium in the urine was not determined. The total moisture of food and feces was taken as the sum of the weight lost in drying, first in a current of warm air at approximately 98 degrees; and second, the weight lost by samples dessicated in a vacuum over calcium chloride for ten days to two weeks. The carbohydrate in the food was determined by difference, according to the formula: (Dry Weight of Food) - (Ash + Protein + Fat) = Carbohydrates.

The method of Van Slyke was used for determining acetone bodies. The results were calculated for total acetone bodies per twenty-four-hour sample or per liter of urine.

The fat in the food was determined by Soxhlet extraction, with annhydrous ethyl ether, of a dried, ground and sieved composite samples for each period. The fat in the feces was determined as follows: Samples of the mixed moist stool as described above, page 27, were weighed from ground glass stoppered weighing bottles. These samples were treated with 0.3 to 0.5 cc. of concentrated hydrochloric acid and allowed to stand for approximately five minutes. A high grade annhydrous sodium sulfate (15 to 20 grams) was then thoroughly mixed with the sample and it was set aside to harden. After one and one-half hours these hard blocks were pulverized and transferred in a fat-free filter paper to extraction thimbles. They were extracted with annhydrous ethyl ether for approximately fifteen to sixteen hours. The ether was distilled on a water bath, and the residue taken up in petroleum ether (B. P. below 60 degrees). These were filtered into weighed flasks and the solvent again distilled on a water bath. When the ether odor had disappeared, the sample was put into a constant

temperature oven and dried for three to six hours at a temperature of 75 degrees. The flasks were then cooled in a dessicator and weighed. After weighing, the residue was dissolved in 55 cc. of hot benzene and titrated with tenth normal sodium alcoholate. Brom Thymol Blue was used in this titration. This indicator was found to give a better endpoint from green to blue in the light amber colored samples than phenolphthalein with its red alkaline end point. Preliminary titrations of pure samples of benzoic and stearic acid, also slightly colored samples of rancid lard, showed a satisfactory agreement between results with the two indicators.

Triplicate samples were run for all determinations for all food analyses for fecal fats and for urine nitrogens. For the dried weight, nitrogen and calcium of feces and acetone bodies in urine single large samples were prepared and aliquot portions were used for the triplicate determinations. The reader is referred to the description of Collection and Preparation of Samples, pages 26-28, for further detail. The averages of the triplicate results were the values reported.

TABLE V

THE BALANCE PERIODS AND THE MATERIAL FOR ANALYSES
(For all periods)

Character of Diet In Terms of Fat	Date	Total Days	Composite Numbers	Material upon Which Analyses Were Made					
				Feces			Urine		Food
				Fat	N.	Ca	Ketone Bodies	N	
Regular Home Diet	Feb. 13-15	8	I	Analyses on moist alcohol preserved composite samples	Analyses on moist composite samples made from mixed	All analyses upon dried composite samples	All analyses on twenty-four hour toluene pre-served samples	All analyses on composite samples made from the twenty-four hour specimens	All analyses for all periods on composites made from dried samples
	16-20	5	II						
Regular Home Diet With Increased Fat	21-25	5	III						
	26-28 & Mar. 1-2	5	IV						
Regular Home	Apr. 26-28	3	V	Analyses were carried out on daily fresh moist samples from each store	All analyses upon composites made from moist samples	All analyses upon dried composite samples	All analyses on twenty-four hour toluene pre-served samples	All analyses on composite samples made from the twenty-four hour specimens	All analyses for all periods on composites made from dried samples
Regular Home Diet With Decreased Fat	29-30 & May 1	3	VI						
	2-4	3	VII						
	5-7	3	VIII						
	8-10	3	IX						
Regular Home Diet With Increased Fat	11-13	3	X	Analyses were carried out on daily fresh moist samples from each store	All analyses upon composites made from moist samples	All analyses upon dried composite samples	All analyses on twenty-four hour toluene pre-served samples	All analyses on composite samples made from the twenty-four hour specimens	All analyses for all periods on composites made from dried samples
	14-16	3	XI						
	17-19	3	XII						

EXPERIMENTAL RESULTS

Because of the complexity of the problem undertaken, it has seemed best to the author to discuss results under each topic heading rather than after all data have been presented. The regular home diet periods have been looked upon as the normal or usual reaction of the child, and relationships or deviations, during the low fat and high fat series, have been considered from the standpoint of the consistency in the deviations as shown in both subjects, the magnitude of such deviations, and the possible significance of these deviations in the metabolic processes of the child. In the analysis of the data the effect of the various levels of fat intake will be considered in relation to: (1) Protein, carbohydrates and calorie ingestion; (2) Fat in feces and fat retention; (3) the Partition of Fecal Fats; (4) The Excretion of Total Acetone Bodies; (5) The Net Energy Balance; (6) The Distribution of Calories Between Protein, Fat and Carbohydrate; (7) The Nitrogen Retention; (8) The Loss of Calcium and Other Nutrients Through the Feces.

Fat intakes as related to protein, carbohydrate and total caloric ingestion.--The first question to be answered would obviously be: How much fat will a child eat? and the second is, What effect has a given level of fat ingestion on the protein, carbohydrate and caloric values of the diet? In regard to the first, the fat intakes for the three series averaged 59 and 76 grams for the two subjects J and T, respectively, on the regular home diet, 42 and 49 grams on the low fat diets, and 127 and 133 grams on the high fat diets. The higher intakes in each series were ingested

by the elder of the two, Subject T. (Table VI).

The changes in the fat in the diets as described were reflected in proportional changes in the ingestion of other nutrients. In general, these variations were not large and not beyond the range of nutrient intakes found in other studies. The total carbohydrate, as might be anticipated, was inversely proportional to the fat intake. The ratio of fat to carbohydrate varied slightly from one composite to another in each series. (It is difficult to prevent such variations when mixed diets are allowed, unless a pre-analysis on the food is performed.) Since it was the intention here to study variations in fat in diets that were non-ketogenic and yet near the extreme limits probable in a freely selected food intake, the fatty acid to glucose ratios of the diets for the various composites were estimated according to the Wood-yatt formula. (Table XIII). The children were served the customary protein-containing foods in all series, but the actual nitrogen ingested varied somewhat from one series to the next. An increase of approximately 5 per cent in the average protein intake during the low fat periods and a decrease of approximately 14 per cent during the high fat period occurred with both subjects. This change in protein was related undoubtedly to the change in concentration in the food, especially to the substitution of cream for 50 per cent of the milk during the high fat series, and the removal of cream from the milk during the low fat series. The average intake of milk or milk and cream mixed was close to one and one-half pints by measure in all periods. (Table VII).

The total available calories and their percentage distribution between protein, fat, and carbohydrates for all composites are given in Table VIII. The per cents of the total available calories from protein and carbohydrate were inversely proportional

TABLE VI
COMPOSITION OF DIET BY PROXIMATE ANALYSIS BY SUBJECTS AND BY PERIODS
(Average daily)

Composite	Subject J					Subject T				
	Dry Wt. Food.	Ash	Protein n x 6.25	Fat Ether Ext.	Carbohydrate by Difference	Dry Wt. Food	Ash	Protein n x 6.25	Fat Ether Ext.	Carbohydrate by Difference
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Regular Home Diet										
I	214	9.9	42.5	53.2	108.6	352	12.4	58.1	75.3	206.2
II	286	11.9	59.9	66.4	154.8	358	13.9	55.8	75.3	213.0
V	301	12.0	53.4	58.0	177.6	348	13.7	55.2	76.2	202.9
Low Fat Diet										
VI	296	12.3	52.6	47.6	183.5	325	12.5	52.5	51.3	198.7
VII	299	11.9	50.7	44.3	192.1	327	13.9	56.7	47.3	209.1
VIII	329	14.5	59.1	36.7	218.7	385	15.1	64.2	45.5	260.2
IX	341	13.3	47.5	39.6	240.6	409	16.3	51.9	52.3	288.5
High Fat Diet										
III	289	9.1	43.3	121.4	115.2	309	10.0	44.1	118.5	136.4
IV	270	8.9	42.2	96.3	122.6	331	11.0	50.0	123.7	146.3
X	347	11.3	44.4	136.2	155.1	354	12.2	44.6	133.6	163.6
XI	306	10.1	41.8	136.7	117.4	333	11.8	50.2	132.5	138.5
XII	325	9.1	43.7	143.8	128.4	383	11.0	51.0	158.2	162.8
Averages Per Series										
Diet										
Home.....	267	11.3	49.6	59.2	147.0	353	13.3	56.4	75.6	207.4
Low Fat....	316	13.0	52.5	42.1	208.7	382	14.5	58.8	49.1	239.1
High Fat....	307	9.7	43.1	126.9	127.7	342	11.2	48.0	133.3	149.5

TABLE VII
AVERAGE DAILY INTAKE OF MILK AND CREAM

Diet	Subject J.			Subject T.		
	Milk	Cream	Total	Milk	Cream	Total
Regular Home.....	gm. 631	gm. 2	gm. 633	gm. 574	gm. 5	gm. 579
Low Fat.....	634	0	634	631	0	631
High Fat.....	345	255	600	286	252	538

to the fat when the amount of fat ingested was high. The protein calories averaged during the regular home diet series 15.7 and 12.6 for the two subjects J and T respectively, whereas during the high fat series, these were decreased to 9.6 and 9.3 per cent. On the contrary there was no significant change in the protein calories during the low fat series, the figures being 15.4 and 13.7 per cent respectively. It will be noted that both subjects showed a decrease of nearly 150 calories in total net caloric intake during the first six days on the low fat diet (composites VI and VII), while during the next six days (composites VIII and IX), the net caloric intake tended to return to its former level. The average differences (Table VIII) in total available calories between the regular home series and the low fat series were plus 93.0 or 7.0 per cent for Subject J, and minus 111.0 or 6.4 per cent for Subject T. In contrast to this there was a marked increase in calories during the high fat periods in both subjects. This averaged 504 calories or 37.8 per cent for Subject J, and 273 calories or 15.8 per cent for Subject T. Comparing these amounts and variations in food nutrients, in all periods with those from other studies as in Table IX, it is obvious that the extremes in intakes and distribution of available calories in this

TABLE IX

GRAMS OF FOOD INTAKES FROM VARIOUS SOURCES AND THE PERCENTAGE DISTRIBUTION OF CALORIES

Study	Mini- mum	Maxi- mum	Aver- age	Distribution of Calories		
				Mini- mum	Maxi- mum	Aver- age
	gm.	gm.	gm.	Per cent	Per cent	Per cent
Protein						
This study, both sub- jects, all periods	42	64	53	8.3	17.1	12.4
Goodhue.....	42	75	63	10.0	18.0	14.2
Holt and Fales Standard.....	48	59	53	11.0	23.0	15.0
Fat						
This study, both sub- jects, all periods	37	158	81	22.0	65.9	44.1
Goodhue.....	42	123	77	18.0	52.0	37.4
Holt and Fales Standard.....	49	60	55	21.0	51.0	34.0
Carbohydrate						
This study, both sub- jects, all periods	109	289	181	25.8	64.0	43.2
Goodhue.....	146	334	217	32.0	64.0	51.0
Holt and Fales Standard.....	159	195	178	38.0	65.0	51.0
Total Calories						
This study, both sub- jects, all periods	1,088	2,293	1,659			
Goodhue.....	1,345	2,761	1,821			
Holt and Fales Standard.....	1,300	1,600	1,450			

study are approximately those found elsewhere in freely selected home diets. There is no way of knowing what the relationships have been in other studies, between total fat and total caloric intakes, but here there is proof of a direct correlation between increased fat and increased net calories in the diet.

This increase in fat in the diets was not accompanied by any general observations of physical or emotional disturbances and there was no tendency apparent in the latter days of the high fat series to reduce the total amount of food eaten.

Goodhue found no observable evidence of an unhappy result of high fat feeding. Other workers have reported normal children taking as low as 15 grams of fat per day and as high as 123 grams. Holt and Fales, however, on the basis of their study of 106 children as described before, established their well known standard for food intakes. These authors have the following to say in regard to the proper distribution of calories in a diet: "On the whole, one may conclude both from theoretical considerations and from practical observation that a diet in which the fat supplies 35 per cent of the total calories, the protein 15 per cent, and the carbohydrate 50 per cent, is one which meets the nutritive needs of the child after infancy, which is well borne by the digestive system and may be considered a well balanced ration."

It is not necessarily the intention here to infer that this distribution of calories is one "which is not well borne" but rather to raise the issue of the specific evidences of metabolic disturbances which arise from other distributions in well children. These evidences have been sought through a study of the fat lost in feces, the excretion of acetone bodies, the retention of nitrogen and energy, and the loss of calcium in feces.

Fat intakes and fat in feces.--The effect of fat on the

physical character of the feces was definite and perhaps important from the standpoint of the comfort and ease of defecation. All stools during the regular home series were formed, smooth and firm. Those from the low fat diets were not consistently different in weight from those in the other series, but they were hard and waxy in consistency and by gross inspection were not uniform in color or composition. Although undigested food was not visible in them, they were extremely difficult to mix and sieve. The stools from the high fat diets were semi-formed, soft, and tender, and by inspection appeared to be uniform in color and composition. Also they were easy to mix and sieve. The waxy stools in the second instance were associated with a state of constipation as described by the subjects and the mother. No constipation was complained of either during the regular home diet or the high fat diet series. There was no diarrhea or other gastro-intestinal disturbance at any time.

How then did the various levels of fat intake affect the loss of fat in the feces? It will be seen in Table X that there was a slight and irregular reduction in total fat in the feces during the low fat diets, whereas there was a small but consistent increased amount on the high fat diets, compared in both instances with the regular home diet. This is noted especially in the averages and is more marked for the older subject (T). His average fecal fat on the regular home diet was 3.6 grams, on the low fat diet 2.5 grams, and on the high fat diet 4.5 grams. For Subject J there was little difference between the fecal fat on the regular home and the low fat diets (3.2 and 3.1 respectively), but there was a notably greater amount on the high fat (5.3 grams).

The extreme variation in fat intakes, for both subjects, as recorded for the low fat series was from 36.7 to 52.3 grams,

TABLE X

FAT INTAKE, AND LOSS IN FECES, AND COEFFICIENTS OF DIGESTION
(Average Daily)

Composite	Subject J			Subject T		
	Fat		Coeffi- cient	Fat		Coeffi- cient
	Intake gm.	Feces gm.		Intake gm.	Feces gm.	
Regular Home Diet						
I	53.2	2.5	95.3	75.3	3.9	94.8
II	66.4	3.5	94.7	75.3	3.7	95.1
V	58.0	3.5	94.0	76.2	3.3	95.7
Low Fat Diet						
VI	47.6	2.3	95.2	51.3	2.7	94.7
VII	44.3	4.4	90.1	47.3	2.2	95.4
VIII	36.7	3.0	91.8	45.5	3.2	92.9
IX	39.6	2.6	93.5	52.3	2.1	95.9
High Fat Diet						
III	121.4	5.0	95.9	118.5	4.8	95.9
IV	96.3	5.0	94.8	123.6	4.2	96.6
X	136.3	5.8	95.7	133.6	3.8	97.1
XI	136.7	5.3	96.1	132.5	3.0	97.6
XII	143.8	5.2	96.4	158.2	6.7	95.8
Averages Per Period						
Diet						
Home.....	59.2	3.2	94.7	75.6	3.6	95.2
Low Fat.....	41.1	3.1	92.5	49.1	2.5	94.7
High Fat.....	126.9	5.3	95.8	133.3	4.5	96.6

average daily (Table X). The coefficients of digestion on this intake varied from 90.1 to 95.9 with a mean of 93.5 for both subjects. The fat intakes per composite period during the regular home diet series varied from 53.2 to 76.2 grams, with coefficients ranging from 94.0 to 95.7, and a mean of 94.8 for both subjects. The intake per composite period during the high fat diet series varied from 96.3 to 158.2 grams with coefficients ranging from

94.8 to 97.6 with a mean of 96.1 for both subjects. These coefficients were considered highly satisfactory for all levels of ingestion. The fact that the coefficients were slightly lower during the low fat series and higher during the high fat series as compared with the regular home series, should be noted because of the similarity to the findings on adults, discussed elsewhere.

The children studied by Holt, Courtney and Fales (27, 28) on average intakes from 39 to 61 grams of fat daily had coefficients of absorption from 91.5 to 95.7 with a mean of 94.6. Müller found a greater range from 88.2 to 97.0 per cent on fat intakes varying from 28.2 to 53.1 grams.

There was a direct and consistent relation between the amount of fat in the diet and the loss of fat in feces. A day by day stool analysis, such as that carried out during the composite periods lasting from April 26 to May 19, showed quite clearly (Tables XI and XII) the interrelationships between the fat intake, the fat lost in stools, and the dried weight of the stools. When these data on daily stools were arranged in ascending order (Table XI) according to the per cent of the dried weight of the stool as fat, it was evident that the total fecal fat was directly related to the character of the diet. There were 23 stools in all in which the fat in the dried material ranged from 9.0 to 20.9 per cent. Of these 20 occurred during the low fat, one during the high fat and two during the regular home diet series. On the contrary, of 22 stools with fat ranging from 21.6 to 60.0 per cent of the total dried weight, 18 were from the high fat, 2 only were from low fat and 2 were from the regular home diet series.

Furthermore, the strikingly consistent relation between the total grams of fecal fat per stool and the fat intake (Table XII) was shown when these data were arranged in the order of in-

TABLE XI

THE PER CENT OF FAT IN STOOLS AS RELATED TO THE DIET AND THE
TOTAL DRY WEIGHT OF THE STOOLS
(Stools collected from April 26 to May 19)

Number	Diet	Fat Dry Wt.	Stool Dry Wt.	Number	Diet	Fat Dry Wt.	Stool Dry Wt.
		Per cent	gm.			Per cent	gm.
1	Low Fat	9.0	26.2	24	High Fat	21.6	26.9
2	Low Fat	10.0	16.3	25	Low Fat	22.6	16.0
3	Low Fat	11.3	23.8	26	High Fat	22.8	19.4
4	Low Fat	12.7	17.3	27	High Fat	24.5	24.3
5	Home	13.7	40.6	28	High Fat	26.3	14.9
6	Low Fat	13.8	26.4	29	Home	27.9	29.3
7	Low Fat	13.9	16.8	30	Low Fat	28.4	9.7
8	Low Fat	14.0	26.8	31	High Fat	29.6	11.2
9	Home	14.1	30.4	32	High Fat	30.4	12.9
10	Low Fat	15.6	13.0	33	High Fat	30.6	20.3
11	Low Fat	15.5	33.7	34	Home	31.7	7.2
12	Low Fat	15.6	26.7	35	High Fat	32.6	14.6
13	Low Fat	16.8	6.7	36	High Fat	32.8	14.3
14	Low Fat	18.1	11.5	37	High Fat	35.5	23.4
15	Low Fat	18.2	16.6	38	High Fat	36.3	11.0
16	High Fat	18.3	18.1	39	High Fat	37.3	11.6
17	Low Fat	19.6	9.5	40	High Fat	38.0	10.8
18	Low Fat	19.6	16.8	41	High Fat	40.9	18.3
19	Low Fat	19.9	23.2	42	High Fat	41.6	13.7
20	Low Fat	20.1	20.2	43	High Fat	41.9	9.6
21	Low Fat	20.7	9.8	44	High Fat	43.5	11.9
22	Low Fat	20.7	9.8	45	High Fat	60.0	7.7
23	Low Fat	20.9	14.4				

creasing grams of fat per stool. It was evident here, however, that the total solids of the stool also affected the total grams of fat lost per stool. For example, there were 11 stools which contained from 3.02 to 3.99 grams of fat each; 7 of these were low fat intakes stools with an average dry weight of 18.6 grams, while 4 were high fat intakes with an average dry weight of 13.8 grams. In other words, the total grams of fat lost per stool were nearly the same, but the per cent of the dried weight of the stool as fat was higher on the high fat diet. This was shown again when the average dry weight of feces per composite period was

TABLE XII

FAT IN STOOLS AS RELATED TO FAT INTAKE AND FECAL SOLIDS
(Stools from April 26 to May 19)

Subject J			Subject T		
Diet	Fat Per Stool	Dry Wt. Stool	Diet	Fat Per Stool	Dry Wt. Stool
	gm.	gm.		gm.	gm.
Low Fat	1.13	6.7	Low Fat	1.63	16.3
Low Fat	2.03	9.8	Low Fat	1.87	9.5
Low Fat	2.08	11.5	Low Fat	2.02	13.0
Home	2.28	7.2	Low Fat	2.03	9.8
Low Fat	2.86	9.7	Low Fat	2.19	17.3
Low Fat	3.31	16.8	Low Fat	2.35	16.8
High Fat	3.31	11.2	Low Fat	2.36	26.2
Low Fat	3.62	16.0	Low Fat	2.69	23.8
Low Fat	3.92	12.9	Low Fat	3.02	14.4
High Fat	4.02	9.6	Low Fat	3.02	16.6
Low Fat	4.07	20.2	High Fat	3.32	18.1
Low Fat	4.17	26.7	Low Fat	3.65	26.4
Low Fat	4.63	23.2	Low Fat	3.65	26.8
High Fat	4.72	14.6	High Fat	3.92	14.9
High Fat	5.18	11.9	High Fat	3.99	11.0
Low Fat	5.22	33.7	High Fat	4.27	10.8
High Fat	5.62	13.7	High Fat	4.31	11.6
High Fat	5.72	24.3	Home	4.31	30.4
High Fat	5.81	26.9	High Fat	4.42	7.7
High Fat	6.18	20.3	High Fat	4.42	19.4
Home	8.19	29.3	High Fat	4.70	14.3
High Fat	8.30	23.4	Home	5.57	40.6
			High Fat	7.48	18.3

arranged in ascending order as in Table XX. As an example: For Subject T during the low fat diet composite IX the average daily dried weight of the feces was 16.2 and the grams of fat lost was 2.1, while in high fat period XII, the average dried weight of feces was again 16.2 grams, but the total average daily fat lost in this period was 6.7 grams. Thus, on the basis of averages per series and on actual day by day analysis it is shown that fat in feces is directly related to the total fat in the diet, but an increased weight of stool at any level of fat intake will tend to increase the total grams of fat lost per stool.

This increase in total fat in feces with increased intake is contrary to the finding of Fleming and Hutchinson (13), and their co-workers. Unfortunately the data of these workers on children were not reported in great detail, but it seems certain that they examined single specimens of feces and that they were dealing with levels of fat ingestion that were moderate and nearly the same in all subjects, as compared with the levels of fat ingested in the various periods of this study.

From these data it is concluded that: (1) on moderate or low intakes of fat as a part of a mixed diet, the absorption will range from 90 to 96 per cent, while on higher intakes more favorable coefficients of from 94 to 98 per cent may be obtained; (2) these coefficients of absorption will vary directly within these narrow limits with the amount of fat ingested and to a degree with the total dry weight of fecal material; (3) the total grams of fat absorbed are directly proportional to the amount of fat ingested.

Whether the relatively small increase or decrease in fat in feces corresponding to the dietary changes recorded here were fluctuations in food residues or whether they were the results of changes in some elimination process can not be determined from the data presented.

Intakes and the partition of fecal fats.--It is well known that fecal fat is not a single chemical entity, but is a mixture of triglycerides, fatty acids, soaps, sterols, phospholipins and perhaps other unrecognized ether soluble materials. These ether soluble materials may be fractionated as neutral fat, free fatty acids, and soaps, or they may be fractionated as total fatty acids (free fatty acids plus fatty acids liberated from soaps) and neutral fat. The latter would obviously include triglycerides

and sterols. The data for fatty acid values are not chemically exact figures because of the fact that a mixture of fatty acids of unknown composition and molecular weights are titrated and calculated here as though they were known to be stearic acid. The assumption is made, of course, that the composition of this mixture is nearly the same in all stools. The soundness of interpretation of data on fat partition obtained in this way depends absolutely upon the validity of this assumption. The present study was extended to a determination of the latter fractions, i.e., total fatty acids and neutral fat.

The neutral fat fraction was found to be directly proportional to the total fat lost in the feces as shown by Tables XIII and XIV, and by Chart A. When the running averages for total fat and for neutral fat were calculated, the curves were much alike in conformation. Similarly constructed curves for the fatty acid fraction, Chart A, on the contrary, did not follow consistently the total fat and neutral fat curves, especially during the low fat series. Nevertheless, while the variations in the first two curves were so strikingly the same in direction that they were alike in configuration, the lines were by no means parallel. One of the interesting features of the data presented here is the extreme variations in the per cent of the total as neutral fat. Individual stool analysis, during the last twenty-four consecutive days of the study, showed the extreme range per stool to be from 26.6 to 93.2 per cent¹ of the total as neutral fat (Table XIII). These variations in per cent of the neutral fraction occurred at all levels of fat intake. For both subjects the fraction of the total fat (Table XIV) as neutral materials ranged from 34.3 to 73.5 per cent during the regular home diet

¹Subject T showed only a trace of neutral fat on one day.

TABLE XIII

TOTAL FAT AND FAT DISTRIBUTION IN STOOLS
(Individual stool analysis)

Composite	Subject J							Subject T								
	Dry Wt. Stool	Total Fat	Fatty Acid	Calcium As Stearic	Neutral Fat	Dry Wt. As Fat	Total Fat As		Dry Wt. Stool	Total Fat	Fatty Acid	Calcium As Stearic	Neutral Fat	Dry Wt. As Fat	Total Fat As	
							Fatty Acids	Neutral Fat							Fatty Acids	Neutral Fat
	gm.	gm.	gm.	gm.	gm.	Per cent	Per cent	Per cent	gm.	gm.	gm.	gm.	gm.	Per cent	Per cent	Per cent
V																
Apr. 27	7.2	2.28	1.39	0.89	2.28	31.7	60.9	29.1	30.4	4.31	2.97	1.37	14.1	68.2	31.8	
28	No stool								No stool							
29	29.3	8.19	5.51	2.68	27.9	67.0	33.0	40.6	5.57	3.44	2.13	13.7	61.8	38.2		
VI 30	16.0	3.62	2.61	1.01	22.6	72.1	27.9	16.8	2.35	1.36	1.00	13.9	57.4	42.6		
May 1	16.8	3.31	2.43	0.88	19.6	73.4	26.6	14.4	3.02	3.02	0.00	20.9	100.0			
2	No stool								23.8	2.69	0.52	2.17	11.3	19.3	80.7	
VII 3	12.9	3.92	2.12	1.80	30.4	54.1	45.9	16.6	3.02	1.65	1.37	18.2	54.6	45.4		
4	33.7	5.22	0.75	4.47	15.5	14.3	85.7	16.3	1.63	0.23	1.40	10.0	14.0	86.0		
5	20.2	4.07	2.17	1.90	20.1	53.1	46.9	9.8	2.03	0.83	1.20	20.7	40.0	60.0		
VIII 6	9.8	2.03	0.83	1.20	20.7	40.9	59.1	26.8	3.65	1.23	2.42	14.0	33.7	66.3		
7	26.7	4.17	1.66	2.51	15.6	39.8	60.2	17.3	2.19	0.52	1.67	12.7	23.7	76.3		
8	9.7	2.86	0.81	2.05	28.4	28.3	71.7	26.4	3.65	0.80	2.85	13.8	21.9	78.1		
IX 9	23.2	4.63	1.84	2.79	19.9	39.8	60.2	26.4	2.36	0.77	1.59	9.0	32.6	67.4		
10	6.7	1.13	0.44	0.69	16.8	30.0	70.0	No stool	No stool							
11	11.5	2.08	0.87	1.21	18.1	41.3	58.7	9.5	1.87	0.59	1.28	19.6	31.5	69.5		
X 12	24.3	5.72	2.35	3.37	24.5	41.1	58.9	13.0	2.02	0.57	1.45	15.5	28.2	71.8		
13	11.2	3.31	0.44	2.87	29.6	13.3	86.7	14.9	3.92	0.56	2.36	26.3	14.3	85.7		
14	23.4	8.30	3.16	5.14	36.5	38.1	61.9	10.8	3.32	1.31	2.21	18.3	39.4	60.6		
									4.27	1.53	2.74	38.0	35.8	64.2		

TABLE XIII--CONTINUED

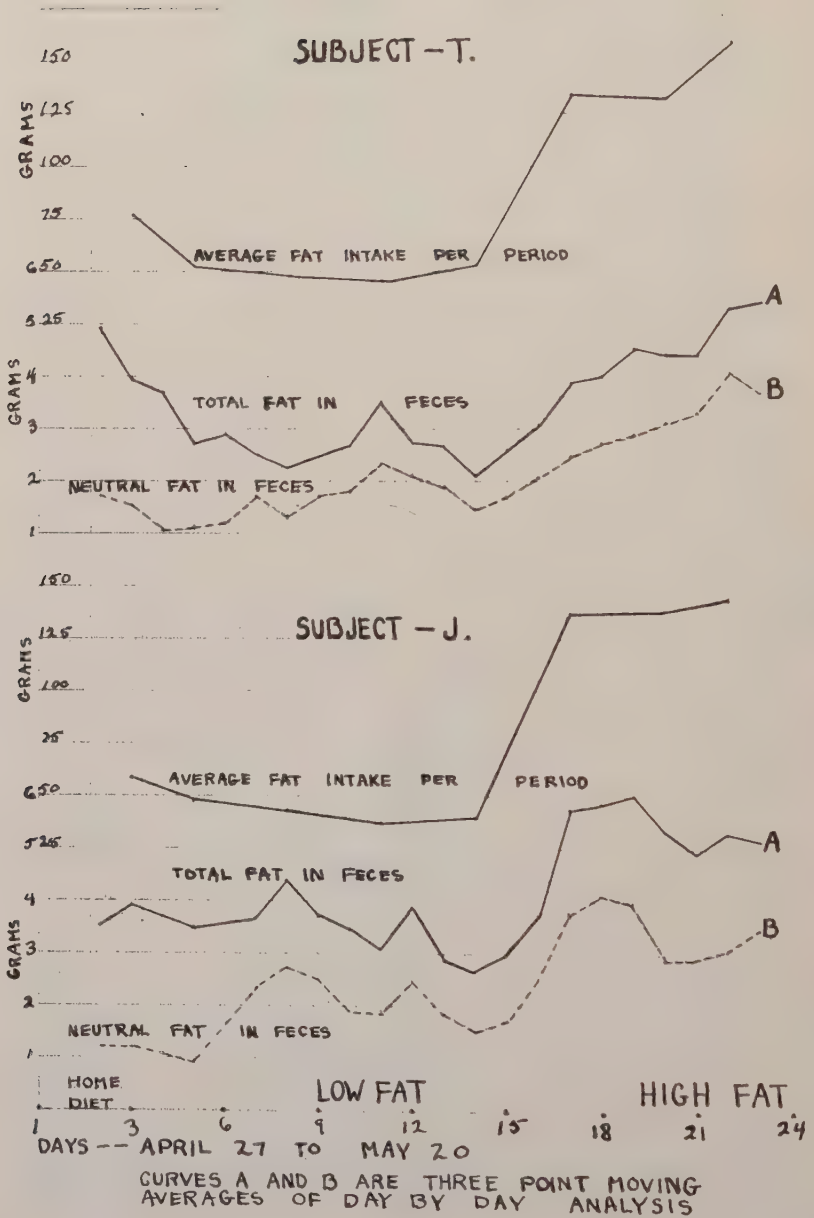
	Subject J										Subject T									
	Dry Wt.					Total Fat as					Dry Wt.					Total Fat As				
	gm.	gm.	Fatty Acid	Calcium As	Natural Fat	Dry Wt.	Fatty Acids	Neutral Fat	Per cent	Per cent	gm.	Per cent	gm.	Fatty Acid	Calcium As	Neutral Fat	Dry Wt.	Fatty Acids	Neutral Fat	Per cent
Composite	26.9	5.81	1.56	4.26	4.26	21.6	26.9	73.1	Per cent	Per cent	gm.	Per cent	gm.	Per cent	gm.	Per cent	gm.	Per cent	Per cent	Per cent
	9.6	4.02	1.54	2.48	2.48	41.9	38.1	61.9	73.1	73.1	19.4	22.8	3.25	26.7	2.15	22.8	26.7	26.7	73.3	73.3
	20.3	6.18	4.37	1.81	1.81	30.6	70.7	29.3	61.9	61.9	14.3	32.8	2.55	45.7	2.15	32.8	45.7	45.7	54.3	54.3
	14.6	4.72	0.32	4.50	4.50	32.6	6.8	93.2	29.3	29.3	No stool	...	...	...	...	...	...	...	...	...
XII 18	11.9	5.18	1.27	3.91	3.91	43.5	24.5	75.5	93.2	93.2	11.0	36.3	3.40	14.8	0.59	36.3	36.3	14.8	85.2	85.2
	13.7	5.62	3.52	2.10	2.10	41.6	62.6	37.5	75.5	75.5	7.7	40.9	3.79	31.1	2.48	40.9	40.9	31.1	66.9	66.9
											18.3	37.3	2.10	51.3	2.21	37.3	37.3	51.3	48.7	48.7

TABLE XIV

FAT AND FAT DISTRIBUTION IN STOOLS
(Average per stool per composite)

Composite	Subject J							Subject T								
	Average Dry Wt. Per Stool	Total Fat	Fatty Acid Calcium As	Neutral Fat	Ratio F.A. M.M.	Dry Wt. As Fat	Total Fat As		Average Dry Wt. Per Stool	Total Fat	Fatty Acid Calcium As	Neutral Fat	Ratio F.A. M.M.	Dry Wt. As Fat	Total Fat As	
							Per cent	Per cent							Per cent	Per cent
I	10.6	2.49				23.5	26.5	73.5	15.8	3.72	2.77	0.95	2.20	23.5	74.0	36.0
II	13.9	3.50	2.32	1.18	1.96	25.2	66.3	33.7	19.4	5.94	4.35	1.59	2.79	30.6	73.3	36.7
III	15.9	4.99	3.59	1.40	2.57	31.4	71.9	28.1	19.4	4.16	1.75	2.41	0.73	26.4	42.0	58.0
IV	15.3	5.02	2.31	2.71	0.85	32.8	46.0	54.0	15.8	4.16	1.75	2.41	0.73	26.4	42.0	58.0
V	18.2	5.24	3.45	1.79	1.92	28.7	65.7	34.3	35.5	4.99	3.20	1.79	1.80	14.0	64.1	35.9
VI	16.4	3.46	2.52	0.94	2.68	21.1	72.8	27.2	18.3	2.68	1.63	1.05	1.55	14.6	60.9	39.1
VII	22.3	4.40	1.68	2.72	0.62	19.7	38.2	61.8	14.2	2.23	0.90	1.33	0.68	15.7	40.4	59.6
VIII	15.4	3.02	1.10	1.92	0.57	19.6	36.4	63.6	23.4	3.16	0.85	2.31	0.37	13.4	26.9	73.1
IX	13.8	2.61	1.05	1.56	0.69	18.9	40.2	59.8	16.2	2.08	0.64	1.44	0.44	12.8	30.8	69.2
X	19.6	5.77	1.98	3.79	0.52	29.4	34.3	65.7	14.6	3.83	1.13	2.70	0.42	26.2	29.5	70.5
XI	18.9	5.33	2.49	2.85	0.81	28.2	46.7	53.3	16.8	5.05	1.66	2.90	0.57	27.2	36.4	63.6
XII	13.4	5.17	1.70	3.47	0.49	38.6	32.9	67.1	14.6	5.05	1.47	3.58	0.41	34.6	29.1	70.9
Average Per Period																
Diet																
Home	14.2	3.74	2.89	1.48	1.95	26.3	57.2	42.8	25.6	4.36	2.99	1.37	2.19	17.0	64.4	35.6
Low																
Fat	17.0	3.37	1.59	1.78	0.89	19.8	47.2	52.8	18.0	2.54	1.00	1.53	0.65	14.1	39.0	61.0
High																
Fat	16.6	5.25	2.41	2.84	0.85	31.0	45.9	54.1	16.2	4.71	2.07	2.64	0.79	29.7	62.9	37.1

CHART A. FAT INTAKE AND OUTPUT.



periods, from 27.2 to 73.1 per cent during the low fat diet periods, and from 28.1 to 73.1 per cent during the high fat diet periods.

In general when the total grams of fat in the feces were reduced, the neutral fat remained relatively high. That is, in both subjects there seemed to be a greater resistance to a decrease in the grams of neutral fat than there was in the grams of fatty acids excreted. This is shown in the shift in the percentage distribution of the total, between neutral fat and fatty acids and also in the total grams of neutral fat excreted (Tables XIII and XIV). The averages per composite period for neutral fat for Subjects J and T respectively were 1.48 and 1.37 grams on the regular home diets, 1.78 and 1.53 on the low fat diets, and 2.84 and 2.64 on the high fat diets. The fatty acids per composite period were 2.89 and 2.99 grams, 1.59 and 1.00 grams, and 2.41 and 2.07 grams for the regular home, low fat and high fat series respectively. Thus, when the fat intake was changed from 50 to 75 grams (home diet) to 100 to 150 grams (high fat diet), there was a doubling in the amount of neutral fat lost but a negligible decrease in the fatty acid fraction (Table XIV and Chart A).

When all of the data were summarized by composite period, Table XIV and the ratios of fatty acids to neutral fat were calculated, it developed that during the composite periods II and V, when the diet ingested contained moderate amounts of fat, the ratio of fatty acids to neutral fat was 1.96 and 1.92 for Subject J, and 2.91 and 1.75 for Subject T. It may be significant that these were regular home diet periods in which the level of fat ingestion was of long standing. Presumably therefore this distribution was the result of a well established equilibrium in the gastro-intestinal tract. When the data are examined from this

point of view, the consecutive composite periods II, III, and IV, and V to VII, inclusively, do seem to be periods of changing distribution. For example, during the low fat period VI the ratios of fatty acids to neutral fat were similar to those in composite V,¹ being 2.68 and 1.55 for the two subjects. During the succeeding low fat periods there was a progressive decrease in the fatty acid fraction, with the neutral fat remaining near or slightly above that in the previous periods, causing a drop in ratios to a low of 0.37 and 0.69 for the two subjects. On the other hand, the high fat period III, immediately following period II, showed a similar low per cent of neutral fat for both subjects. There was a relative decrease in fatty acids while the neutral fat remained high during the next five days, period IV, which resulted in a change in the per cent of the total as neutral fat and a drop in the ratio to 0.85 and 0.75, respectively.

During the high fat periods X to XII immediately following the low fat period IX, the ratios of fatty acid to neutral fat remained low, although there was an increase in the grams in both fractions of material. Whether these new relations in periods IV, IX, and XII represented new equilibriums or whether with longer periods the ultimate result would have been to return to the ratios found in periods II and V are moot questions.

It would appear from this that no interpretation of a given percentage distribution of fat in feces can be made unless a sufficient period is allowed for establishment of an equilibrium, for which more exact time limits must be elucidated.

Within the limitations as pointed out, in regard (1) to the nature of the mixtures being separated and (2) to the element

¹Composite V is not consecutive with composite IV but is with composite VI. See Table V.

of time for establishing equilibriums, the data presented here indicate, first, that when the fat intake is very low, the neutral fraction of the fecal fat remains relatively high, and the reduction of total fecal fat is largely at the expense of the fatty acid fraction, and second, that when the fat in the diet is high, the total fecal fat is increased through an increase in the neutral with little change in the fatty acid fraction.

Obviously this does not prove that fat in feces is a true food residue, rather than an excretion product. In the absence of definite proof to the contrary, it seems reasonable to suppose that on relatively low fat diets with stools that are normal in total solids, the neutral fat fraction may be maintained by fatty materials from cell desquamation, bacterial growth and non-saponifiable increments in the ingested fat, and that as long as activity is maintained in the gastro-intestinal tract, this type of material would continue to be discarded to a degree proportional to the total activity. On the other hand, the total increase in neutral material on the high fat intake may be due in part to an increase in the non-saponifiable material ingested with fat, and in part to unsplit glycerides.

The low excretion of fatty acids during the low fat intakes would indicate simply a more complete absorption. From this point of view the fatty acid excretion in the regular home and high fat series may be assumed to be a waste through failure to absorb. The question of the relationship between fatty acid excretion and calcium is considered under calcium loss in feces.

Fat intake and the excretion of total acetone bodies.--

Since data were not available in the literature on the usual variations in excretion by normal children living at home on freely selected diets, it was necessary to establish the range of excretion occurring on the regular home diet before any effect from increasing or decreasing fat intake could be demonstrated. The total acetone bodies excreted per twenty-four hours for the entire 83 days, including both subjects, ranged from a trace to 938.1 milligrams (Table XV). A critical analysis of the data in this table showed striking fluctuations in the amounts excreted in all periods, that were independent of the fat intake or the fatty-acid to glucose ratios of the diets. For example, on the tenth day of the low fat series, May 8, Subject J excreted 76.6 milligrams while on the eleventh day of the same series, May 9, her excretion was only 16.9 milligrams or less than one-fourth as much. Likewise on the third day of the first regular home diet period February 15, the same subject excreted 304.2 milligrams whereas three days later, February 18, on the same fat intake the excretion was reduced to a trace. Similar variations can be found, by those interested, in the excretion of Subject T.

Nevertheless when the data in Table XV were arranged in the order of ascending weights (Table XVI) and tabulated by 20 milligram intervals (Table XVII) it was found that on 19 out of 21, or 90.4 per cent of the days, the range in the excretion on the regular home diet series was from a trace to 60 milligrams. The average for the series including the two days above 60 milligrams was 44.4 milligrams. The total distribution of the 21 days in the series showed 4 days with excretion below 20 milligrams, 10 days between 20 and 40 milligrams, 5 days between 40 and 60 milligrams, one day between 60 and 80 milligrams and one day only

TABLE XV

DAILY TOTAL ACETONE BODIES AND THE FATTY ACID TO GLUCOSE RATIO
(By composite period and subject)

Com- posite	Subject J				Subject T			
	Acetone	Aver- age	F.A.*	Per cent of Total Calories as Fat	Acetone	Aver- age	F.A.*	Per cent of Total Calories as Fat
	mgm.	mgm.	G		mgm.	mgm.	G	
I. Febr.								
13	23.0							
14	47.2	124.8	1:2.0	44.1	22.0	40.8	1:2.6	38.7
15	304.2				59.5			
II. 16	53.7				52.2			
17	31.8				21.7			
18	+	30.3	1:2.3	43.1	45.1	42.9	1:2.7	38.5
19	35.1				65.9			
20	31.0				26.7			
III. 21	34.8				38.8			
22	31.4				38.5			
23	26.1	25.7	1:2.0	63.2	100.3	65.4	1:1.3	60.1
24	8.0				62.0			
25	28.1				87.5			
IV. 26	36.0				175.6			
27	19.7				73.2			
28	98.5	78.8	1:1.5	56.3	286.2	378.3	1:1.4	58.9
Mar. 1	32.3				938.1			
2	207.5				418.4			
Apr. 26	19.4				11.0			
V. 27	8.7	20.9	1:3.5	35.1	34.4	21.9	1:2.5	40.5
28	34.6				20.2			
VI. 29	42.9				18.1			
30	6.2	28.2	1:3.2	30.6	6.3	20.4	1:3.7	30.6
May 1	35.5				36.7			
VII. 2	14.4				38.7			
3	32.6	29.4	1:3.9	28.2	23.1	31.3	1:3.7	28.6
4	41.2				32.1			
VIII. 5	36.7				38.3			
6	19.9	28.9	1:4.4	22.0	13.1	30.7	1:4.3	23.9
7	30.2				40.7			
IX. 8	76.6				60.7			
9	16.9	38.5	1:4.8	22.9	45.8	35.5	1:4.5	25.9
10	22.0				60.1			
X. 11	38.2				38.5			
12	33.8	45.6	1:1.4	61.1	33.3	55.1	1:1.4	59.8
13	64.9				93.6			
XI. 14	88.0				55.8			
15	67.5	75.7	1:1.1	65.9	56.8	59.8	1:1.2	61.8
16	71.5				66.8			
XII. 17	106.0				69.2			
18	74.6	70.0	1:1.1	64.9	52.1	65.4	1:1.2	62.5
19	29.3				61.1			

$$\frac{*F.A.}{G} = \frac{0.46P. + 0.9F.}{0.56P. + 0.1F. + G}$$

TABLE XVI

DAILY EXCRETION OF ACETONE BODIES AS RELATED TO DIET AND URINE VOLUME**
(Arranged in increasing order of amount)

Sub- ject	Diet	Acetone	Volume Urine	Sub- ject	Diet	Acetone	Volume Urine
		mgm.	cc.			mgm.	cc.
J	Home	trace	687	T	Low Fat	40.7	1,095
J	Low Fat	6.2	830	J	Low Fat	41.2	665
T	Low Fat	6.3	850	J	Low Fat	42.9	686
J	High Fat	8.0	537	T	Home	45.1	700
J	Home	8.7	758	T	Low Fat	45.8	839
T	Home	11.0	738	J	Home	47.2	560
T	Low Fat	13.1	880	T	High Fat	52.1	420
J	Low Fat	14.4	645	T	Home	52.2	639
J	Low Fat	16.9	853	J	Home	53.7	698
T	Low Fat	18.1	730	T	High Fat	55.8	450
J	Home	19.4	653	T	High Fat	56.8	439
J	High Fat	19.7	566*	T	Home	59.5	600
J	Low Fat	19.9	658				
T	Home	20.2	742	T	Low Fat	60.1	655
T	Home	21.7	795	T	Low Fat	60.7	875
T	Home	22.0	740	T	High Fat	61.1	425
J	Low Fat	22.0	738	T	High Fat	62.0	500
J	Home	23.0	1,380	J	High Fat	64.9	595
T	Low Fat	23.1	583	T	Home	65.9	830
J	High Fat	26.1	502	T	High Fat	66.8	518
T	Home	26.7	489	J	High Fat	67.5	324
J	High Fat	28.1	596	T	High Fat	69.2	547
J	High Fat	29.3	492	J	High Fat	71.5	370
J	Low Fat	30.2	870	T	High Fat	73.2	590*
J	Home	31.0	480	J	High Fat	74.6	430
J	High Fat	31.4	398	J	Low Fat	76.6	970
J	Home	31.8	610				
T	Low Fat	32.1	740	T	High Fat	87.5	519
J	High Fat	32.3	449*	J	High Fat	88.0	438
J	Low Fat	32.6	625	T	High Fat	93.6	740
T	High Fat	33.3	585	J	High Fat	98.5	722*
J	High Fat	33.8	568				
T	Home	34.4	730	T	High Fat	100.3	417
J	Home	34.6	644	J	High Fat	106.0	515
J	High Fat	34.8	561				
J	Home	35.1	644	T	High Fat	175.6	580*
J	Low Fat	35.5	895	J	High Fat	207.5	709*
J	High Fat	36.0	488*	T	High Fat	286.2	708*
J	Low Fat	36.7	690	J	Home	304.2	510
T	Low Fat	36.7	1,080	T	High Fat	418.4	694*
J	High Fat	38.2	770	T	High Fat	938.1	574*
T	Low Fat	38.3	755				
T	High Fat	38.5	370				
T	High Fat	38.5	705				
T	Low Fat	38.7	710				
T	High Fat	38.8	559				

*Period IV.

**Based on Table XV.

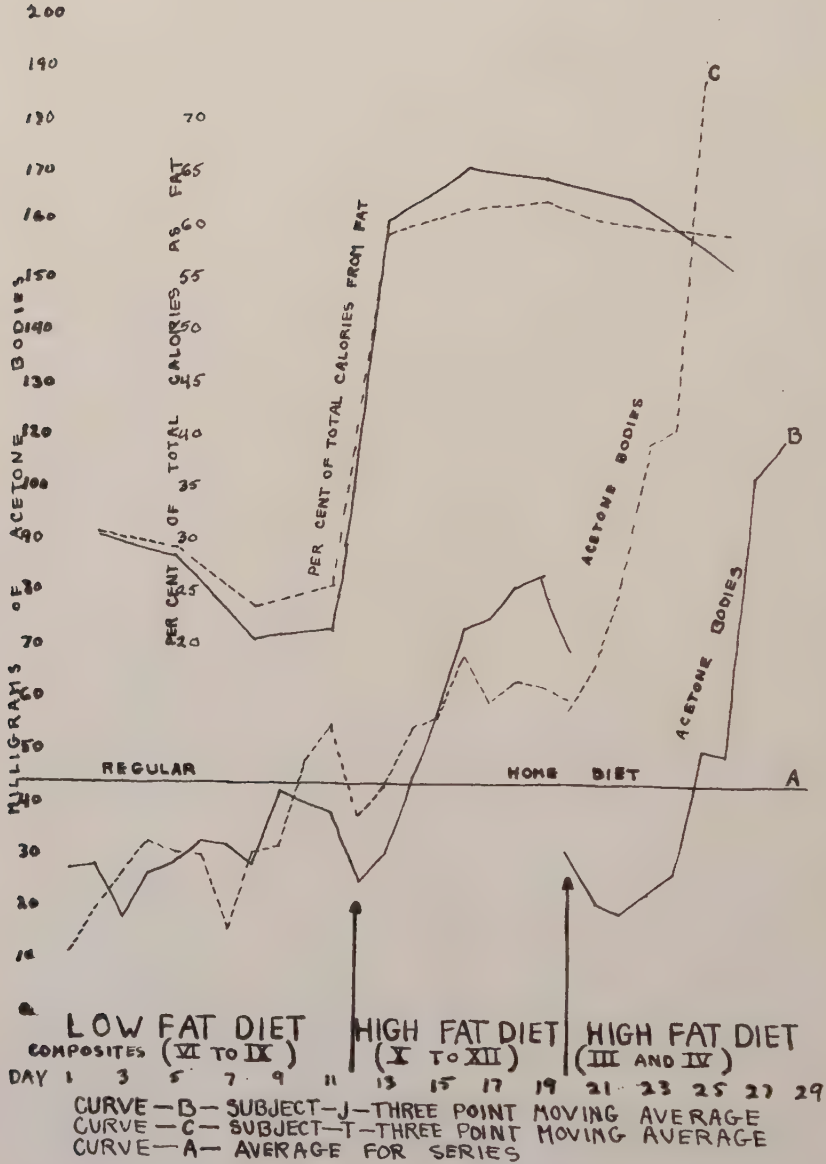
above 80 milligrams.

The average excretion on the low fat diet series was 32.8 milligrams. While this average is slightly below that of the regular home diet series, the range of excretion and the distribution of the days on the low fat were not significantly different from the above. In other words, decreasing the fat in the diet to below 30 per cent of the total calories from fat did not bring about a significant decrease in the excretion of acetone bodies. On the contrary, there was a definite shift toward higher excretions during the high fat intakes. The average excretion exclusive of period IV, was 57.3 milligrams. The total distribution of the 28 well high fat days showed one only with an excretion below 20 milligrams, 14 with excretions from 20 to 60 milligrams and 13 with excretions from 60 to 110 milligrams.

This direct relationship between fat intake and acetone excretion is shown graphically in Chart B. It will be observed that with the onset of whooping cough during the high fat period IV, the curve of excretion rose to a high average of 378.3 milligrams for Subject T.¹ There was also a definite increase in the average for Subject J during this period although her highest average was only 78.8 milligrams. The explanation for these differences in the reaction of the two subjects during this period of incubation of whooping cough is not entirely clear. Subject J showed the first definite symptoms took the form of a slight cold with a mild cough. Neither of the subjects were febrile until two days before the study closed and after they had had whooping cough vaccine. Their temperatures were 99.9 for Subject T, and 100.2 for Subject J at eight o'clock P.M., on this and the follow-

¹please note on Chart B that this curve is not completed. To have done so on the same scale would have required that the chart be doubled in height.

CHART B. DAILY EXCRETION OF TOTAL ACETONE BODIES AS RELATED TO FAT INTAKE.



ing two days. Their treatment during this period was exactly alike with one exception. Subject J only was given 2 to 4 drops of tincture of belladonna four times daily. They both were given vaccine on the first and third day of the period. Their appetites remained good throughout this period, although Subject J reduced her total caloric intake by about 200 calories per day. Subject T, on the contrary, increased his intake by approximately 130 calories per day. Unfortunately there was no way of determining how either child had been infected but apparently both had been exposed, since there was only a few days' delay after Subject J showed symptoms when Subject T began to cough.

TABLE XVII

ANALYSIS OF QUANTITIES OF EXCRETION OF ACETONE BODIES
(By number of days, by subject and by type of diet)

Acetone Bodies (mgm.)	Total	Number of Days on Diet Per Subject				
		Low Fat Diet	Regular Home Diet	High Fat Diet	J	T
120 and above.....	6	..	1	5	2	4
100 to 119.9.....	2	..	..	2	1	1
80 to 99.9.....	4	..	..	4	2	2
60 to 79.9.....	13	3	1	9	5	8
40 to 59.9.....	12	4	5	3	4	8
20 to 39.9.....	33	10	10	13	19	14
1 to 19.9.....	13	7	4	2	9	4
Total.....	83	24	21	38	42	41

The question of whether the total excretion of acetone bodies is related to urine volume has been raised by many workers. An analysis of Table XVI wherein the urine volume as well as the twenty-four excretion is tabulated indicates that there was no correlation between the two quantities in any period in this study. For instance, Subject J excreted 22.0 and 23.0 milligrams in 738 cubic centimeters and 1,380 cubic centimeters of urine while Subject T excreted 23.1, 73.2, and 938.1 milligrams in 583, 590, and 574 cubic centimeters of urine respectively. Because of the high level of the acetone bodies in the urine during period IV these data were calculated both per liter and per twenty-four hours (Table XVIII). The range of concentration in the urine varied from 35 to 1,636 milligrams per liter.

TABLE XVIII
THE EXCRETION OF ACETONE BODIES AS RELATED TO THE
ONSET OF DISEASE
(High fat period IV)

Subject J			Subject T		
Acetone Bodies Per Liter	Urine Volume	Acetone Bodies Per 24 Hrs.	Acetone Bodies Per Liter	Urine Volume	Acetone Bodies Per 24 Hrs.
mgm.	cc.	mgm.	mgm.	cc.	mgm.
77	488	36	303	580	176
35	566	20	124	590	73
136	722	99	404	708	286
72	449	32	1,634	574	938
293	709	208	605	694	418

Although in this study the amounts of fat in the diets were deliberately controlled, the extreme limits in the distribution of the total calories, the grams of fat ingested and in the fatty-acid to glucose ratios of the diets were not appreciably greater than those found in freely selected home diets in other studies (Table IX). It was thought therefore that exclusive of period IV these data could be treated as a single series in determining the range of excretion of total acetone bodies that normally occur in the urine of healthy, active children. From this point of view the above findings can be summarized as follows: (1) an excretion of total acetone bodies above 60 milligrams will rarely occur on diets which yield fatty-acid to glucose ratios of less than 1.0:1.5 (Table XV) or, when not more than 44.0 per cent of the total calories are fat (low fat and regular home diet series); (2) an excretion from 10 to 60 milligrams and from 60 to 110 milligrams will occur with equal frequency on diets in which the fat represents from 56.0 to 66.0 per cent of the total calories (high fat diets in this study); (3) an excretion of more than 110 milligrams will occur frequently when the child is ill or disturbed but rarely occurs in the well child even when the fat is fed at the above high level.

The above findings showing that the excretion of total acetone bodies is increased by moderately high fat intakes, in the presence of relatively large amounts of carbohydrates and other glucose formers and that there is an upper limit of excretion at a given level of fat in the diet, are in harmony with the work of McQuarrie and Keith. These authors found the peak of excretion, on all the diets which they studied, to be during the absorption period. Keeney, Wherrill and their coworkers also found an increased excretion following a single high fat meal composed largely

of cream. It is suggested that acetone bodies produced under these dietary conditions in the disease-free human are the products of energy metabolism.

Fat intake and the net energy balance.--The relation of increased fat intake to the total calories available to the organism would obviously depend not alone on the calories ingested, but on the caloric value of the excreta. From the data assembled here, it was possible to calculate the energy losses and the total net energy of the diet in the various periods. The total available calories were calculated from the grams of protein, fat, and carbohydrate by the following formula:

$$\begin{array}{rclcl} \text{Intake N} \times & - & \text{Feces N} \times & - & \text{Urine N} \times & = & \text{Total available} \\ 6.25 \times 5.65 & - & 6.25 \times 5.65 & - & 6.25 \times 1.25 & & \text{calories from} \\ & & & & & & \text{protein} \end{array}$$

$$\begin{array}{rclcl} \text{Fat} & & \text{Fat} & & \text{Total available} \\ \text{intake} \times 9.45 & - & \text{feces} \times 9.45 & = & \text{calories from} \\ & & & & \text{fat} \end{array}$$

$$\begin{array}{rclcl} \text{Carbohydrate} & & \text{Carbohydrate} & & \text{Total available} \\ \text{intake} \times 4.1 & - & \text{feces} \times 4.1 & = & \text{calories} \\ & & & & \text{from carbohydrate} \end{array}$$

The total caloric intake =

$$\begin{array}{rclcl} \text{Protein} & & \text{Fat} & & \text{Carbohydrate} \\ \text{intake} \times 5.65 & + & \text{intake} \times 9.45 & + & \text{intake} \times 4.1 \end{array}$$

The per cent of the calories that were available showed limited variation with a change in diet in the three series. There was a small but possibly significant increased percentage of energy retention in the high fat periods from 92.4 to 93.5 for one subject and 94.7 to 94.2 for the other. It will be seen from Table XIX that while the proportion of calories from protein, fat, and carbohydrate in the feces varied according to the type of diet served, the total calories absorbed were directly proportional to the intake.

It was first thought that the caloric value of urine during the high fat periods, when the nitrogen excretion was low,

TABLE XIX

THE NET ENERGY BALANCE
(Average daily)

Composite	Subject J					Subject T										
	Caloric Intake					Caloric Output										
	Caloric Output					Caloric Intake										
	Feces					Feces										
	Protein	Fat	Carbo- hydrate	Urine	Total	Per cent of Intake Retained	Protein	Carbo- hydrate	Sum	Urine	Total	Per cent of Intake Retained				
Regular Home Diet																
I.....	1,189	24.9	23.6	5.7	54.2	46.1	100.3	91.6	1,885	35.6	36.9	5.7*	78.2	50.8	129.0	93.1
II.....	1,561	27.7	33.6	11.1	72.4	45.3	117.7	92.4	1,900	42.4	35.0	5.7	83.1	49.2	132.3	93.0
V.....	1,579	24.9	33.6	7.4	65.9	46.1	112.0	93.0	1,863	31.6	31.2	41.8	104.6	46.1	150.7	91.1
Low Fat Diet																
VI.....	1,499	21.5	21.7	11.5	54.7	49.2	103.9	93.0	1,652	35.6	25.5	22.6	83.7	59.4	143.1	91.3
VII.....	1,492	39.0	41.5	29.5	110.0	45.3	155.3	89.6	1,824	31.6	20.8	15.2	67.6	51.6	119.2	92.7
III.....	1,576	31.6	28.4	14.4	74.4	56.3	130.7	91.7	1,860	49.7	30.3	27.5	107.5	61.7	169.2	90.9
IX.....	1,628	28.3	24.5	15.2	68.0	46.9	114.9	92.9	1,970	35.6	20.0	19.8	75.4	50.1	125.5	93.6
High Fat Diet																
XII.....	1,864	24.9	47.3	15.2	87.4	38.3	125.7	93.3	1,928	28.3	45.4	12.3	86.0	40.0	126.0	93.5
IV.....	1,650	24.9	47.3	12.7	84.9	38.3	123.2	92.5	2,052	28.3	39.7	14.8	82.8	44.5	127.3	93.9
X.....	2,174	32.8	54.8	22.1	109.7	39.1	148.8	93.2	2,186	28.3	35.9	13.5	77.7	40.0	117.7	94.6
XI.....	2,008	28.3	50.1	9.4	87.8	38.3	126.1	93.7	2,104	28.3	28.4	9.8	66.5	43.0	109.5	94.8
XII.....	2,128	24.9	49.1	6.2	80.2	34.4	114.6	94.6	2,450	28.3	63.3	7.0*	98.6	38.3	136.9	94.9
Average Per Series																
Diet	1,441	25.9	30.3	8.1	64.2	45.8	110.0	92.4	1,863	36.5	34.4	17.7	88.6	48.7	137.3	92.7
Home.....	1,549	30.1	29.0	17.7	76.8	49.4	126.2	91.9	1,776	38.1	24.2	21.3	83.6	55.6	129.2	92.1
Low Fat..	1,964	27.3	49.7	13.1	90.0	37.7	127.7	93.5	2,143	28.3	42.5	11.5	82.3	41.4	123.7	94.2
High Fat..																

*Available carbohydrate calculated as total carbohydrate difference minus the crude fiber of the diet. The figure is probably low as compared with the other data.

would be influenced by the slight increase in total acetone bodies, thus making the factor 1.25^1 invalid for the urine. Estimation of the caloric equivalent of the acetone excreted, however, showed that the error due to this factor would be very small indeed.

For example, in the low fat period VIII for Subject T, the caloric value of the urine was calculated as 61.7. This represented 7.9 grams of nitrogen in the urine. There was excreted during this period an average of .0307 grams of acetone (total acetone bodies). The caloric value of one gram of acetone is 7.3 calories, therefore the total calories from acetone was $7.3 \times .0307 = 0.22$ calories. If the normal urine were assumed to be entirely free from acetone in the data by which Atwater established his factor of 1.25, then the caloric value of the urine here should be $61.7 + 22$ or 61.92 calories, and the per cent of the intake lost in excreta would change from 9.10 to 9.11 per cent, Table XV. On the other hand, during period IV, Subject T excreted an average of 0.3783 grams of acetone (total acetone bodies). This has a total caloric value of 2.76 calories. The calories lost in the urine then should be 44.5 plus 2.76 or 47.26 calories. The total calories lost then for this period would be 130.06 in place of 127.3 calories. This divided by the intake would mean that the total per cent lost in excreta was 6.34 instead of 6.10 per cent.

From this, it appeared that the factor 1.25 per gram of nitrogen was not invalidated by the loss of acetone bodies during the high fat periods.

These findings definitely support the conclusion of Wang and her co-workers that the total available calories are directly proportional to the intake, but do not agree with their finding that the per cent utilization is the same in all diets and independent of intake. It will be recalled that these workers found a higher loss of calories on their high protein than on their low protein diets, due, they say, to increased excretion in urine and feces. The data presented herein indicates that the per cent of the total calories that are available may be influenced at least within narrow limits by the fat of the diet, as well as the protein. The high average coefficients of digestion for fat of 95.8

¹See p. 11 for discussion of this factor. (This reference is to the complete dissertation, which is in the University of Chicago Libraries.)

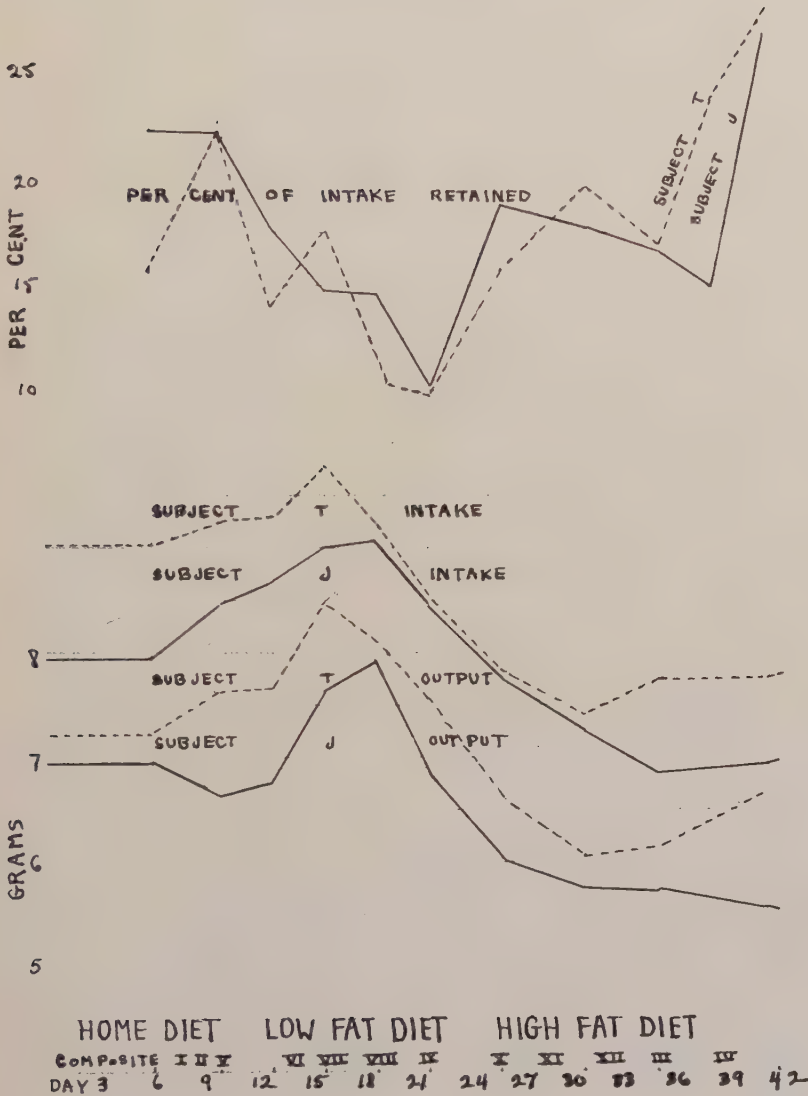
and 96.6 (Table X) on the high fat intakes for Subjects J and T, respectively, paralleled the relatively high coefficients of retention of 93.5 and 94.2 for total energy, and was an increase from the averages of 91.9 and 92.1 for the low fat periods, for Subjects J and T, respectively. These results are in harmony with the recognized low specific dynamic action of fats and the sparing action of fats on protein catabolism. Obviously, the greater the amount of incompletely oxidized nitrogenous end-product in the urine, the higher would be its caloric value.

Fat intakes and nitrogen retention.--Aside from the effect of fat on the total composition and the available energy of the diet, the problem of the interrelation of fat to nitrogen and calcium retention must be worked out before there can be an adequate understanding of the role of fat in the diet. To this end the dried feces samples were subjected to a proximate analysis in a manner similar to that performed on the dried food samples. There were variations in all the periods for both subjects in the coefficient of digestion for protein, as shown in Table XX. These variations did not correlate with any particular level of fat intake, although there were relatively greater deviations from the average for the regular home diet series, during the low fat than during the high fat series. While the per cent of the nitrogen intake retained varied in all periods, the high fat diets favored retention while the low fat intakes were associated with a diminution in the per cent of intake retained (Table XX). It will be observed also from Chart C that the grams of nitrogen retained were directly proportional to the intake, but that the per cent of the intake retained was definitely elevated on the high fat diets. It was impossible in this study to consider separately the factors of total fat and total caloric intake since the high

TABLE XX
NITROGEN BALANCES AND COEFFICIENTS OF DIGESTION
(Average daily)

Composite	Subject J				Subject T											
	Output				Coefficient	Retention		Per cent of Intake								
	Intake	Feces	Urine	Total		Intake	Per cent of Intake									
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.								
Regular Home Diet																
I.....	6.79	0.65	5.93	6.58	6.14	90.1	0.21	2.9	0.99	6.50	7.49	8.31	89.2	1.81	19.6	
II.....	8.47	0.76	5.75	6.51	7.71	90.5	1.96	22.3	8.92	1.19	6.26	7.45	7.73	86.5	1.47	15.6
V.....	8.55	0.65	5.90	6.55	7.90	91.7	2.00	22.3	8.83	0.90	5.87	6.77	7.93	89.7	12.06	22.7
Low Fat Diet																
VI.....	8.42	0.56	6.29	6.85	7.86	92.8	1.57	17.8	10.00	0.97	7.64	8.61	9.03	90.0	1.39	14.0
VII.....	8.11	1.08	5.81	6.89	7.03	86.4	1.22	14.8	9.07	0.86	6.59	7.55	8.21	90.1	1.52	17.6
VIII.....	9.45	0.85	7.15	8.00	8.60	90.5	1.45	14.7	10.27	1.36	7.86	9.22	8.91	86.4	1.05	10.7
IX.....	7.59	0.78	6.03	6.81	6.81	89.7	0.78	10.3	18.30	1.00	6.54	7.52	7.30	87.9	0.76	9.6
High Fat Diet																
XIII.....	6.92	0.73	4.92	5.65	6.19	89.8	1.27	18.8	7.04	0.83	5.08	5.91	6.21	88.6	1.13	15.7
IV.....	6.76	0.74	4.88	5.62	6.02	89.7	1.14	17.6	8.10	0.81	5.66	6.47	7.29	90.1	1.63	19.8
X.....	7.11	0.89	5.05	5.94	6.22	87.3	1.17	16.9	7.13	0.79	5.07	5.86	6.34	88.7	1.17	16.9
XI.....	6.89	0.75	4.93	5.68	5.94	88.1	1.01	14.9	8.03	0.60	5.47	6.07	7.42	92.5	1.96	23.8
XII.....	6.99	0.67	4.35	5.02	6.32	90.0	1.97	27.1	18.17	1.04	4.93	5.97	7.13	87.8	2.20	28.1
Average Per Series																
Diet																
Home.....	7.9	6.9	5.8	6.5	7.2		1.4	17.7	9.0	1.0	6.2	7.2	8.0		1.8	20.0
Low Fat.....	8.4	8.2	6.3	7.1	7.6		1.3	15.5	9.4	1.1	7.2	8.2	8.4		1.8	22.6
High Fat.....	6.9	7.6	4.8	5.6	6.1		1.4	20.3	7.7	0.8	5.3	6.0	6.9		1.6	20.8

SHOWING THE RELATIVELY LOW RETENTION
ON THE LOW FAT, LOW CALORIE DIETS.



fat periods were characterized by relatively high caloric intakes, thus, the nitrogen retention showed the same general correlation with the total available calories in the diet as with the total fat. These results are in complete harmony with the relation of fat and total energy intake to nitrogen retention as found by other workers. Many explanations for these phenomena might be advanced. When the organism is abundantly or excessively supplied with energy the excess is stored. This process involves the multiplication of structure cells over the entire body with perhaps considerable increase in the total surface. Hence depositing fat may be associated with nitrogen deposition. Also there is a rapidly accumulating literature on the function of the nitrogen base choline in the intermediary metabolism of fats and if it is correct that the formation of phospholipins is one step in the anabolic fat processes then a plethora of fat to the liver would be likely to be associated with a diversion of nitrogen molecules to meet demands for the formation of the choline and finally the lipin molecules.

Fat intakes and the loss of other nutrients including calcium in the feces.--The most striking relations found between the total weight of feces and the loss of nutrients were in regard to total calcium and protein (Chart D). An inspection of Table XXI, wherein the average daily grams of dried feces per composite were arranged in order of increasing weight, reveals that whereas there was in general a direct relation between the total dry weight of the feces and the total grams of the above nutrients, the fat was related to the level of intake as well as the total dry weight of feces (Chart D). Interestingly enough, the crude fiber in the food showed no consistent relation to the total dried weight of the feces or to the total loss of carbohydrate.

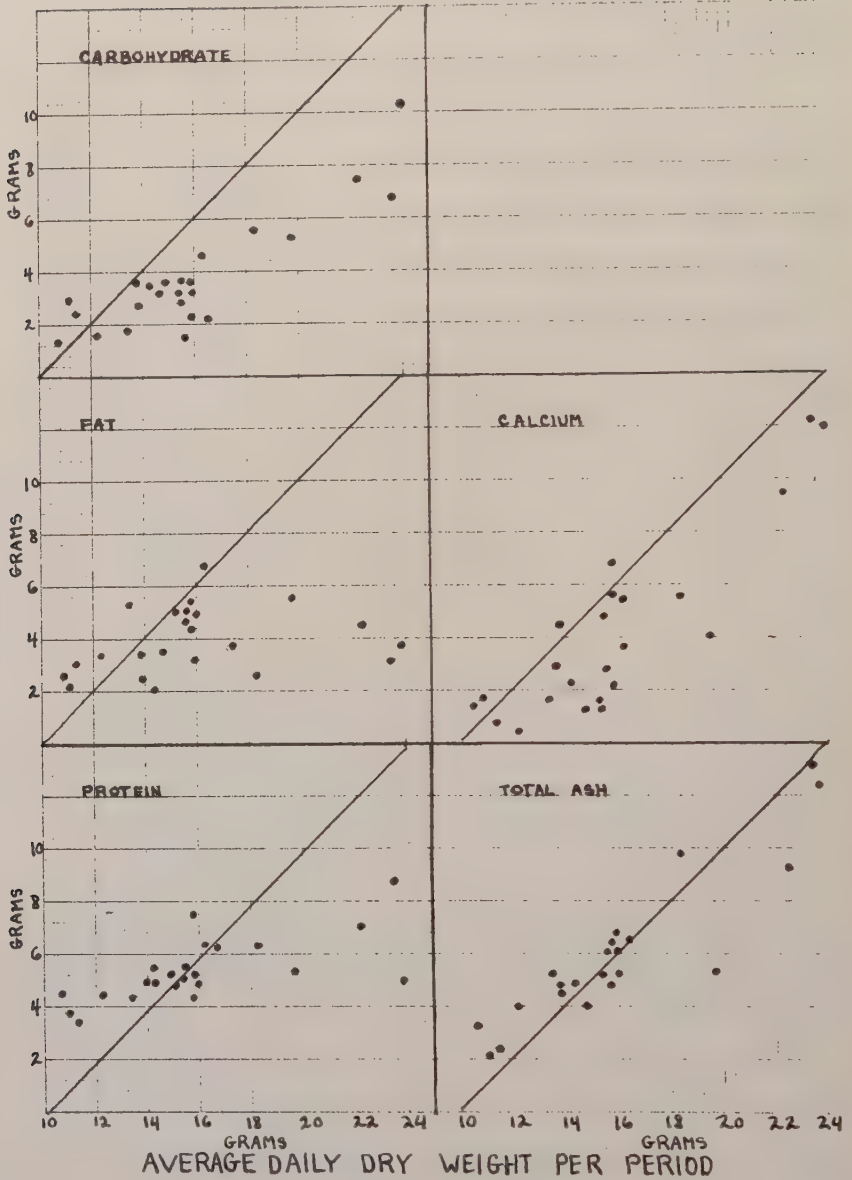
TABLE XXI

THE LOSS OF CALCIUM AND OTHER NUTRIENTS IN FECES

Subject J									
Composite	Series	Dried Feces	Distribution of Weight						Total Dry Weight of Diet
			Protein	Ash	Calcium	Intake* Crude* Fiber	Total Carbohy- drate	Fat	
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
I	Home	10.6	4.4	2.3	0.57	0.7	1.4	2.5	
VI	Low Fat	10.9	3.8	2.0	0.58	2.3	2.8	2.3	
V	Home	12.2	4.4	2.5	0.52	1.7	1.8	3.5	
XII	High Fat	13.4	4.4	2.3	0.58	1.4	1.5	5.2	
II	Home	13.9	4.9	2.7	0.62	0.9	2.7	3.5	
IX	Low Fat	13.9	5.0	2.6	0.71	2.9	3.7	2.6	
IV	High Fat	15.3	4.4	2.8	0.58	0.9	3.1	5.0	
VIII	Low Fat	15.5	5.6	3.1	0.84	2.2	3.5	3.0	
XI	High Fat	15.6	5.0	3.0	0.78	0.9	2.3	5.3	
III	High Fat	15.9	4.4	2.8	0.60	1.3	3.7	5.0	
X	High Fat	19.6	5.6	2.8	0.70	1.7	5.4	5.8	
VII	Low Fat	22.3	6.9	3.8	0.97	2.3	7.2	4.4	
Subject T									
I	Home	...	6.3	...	...	1.4	...	3.9	
XI	High Fat	11.3	3.8	2.1	0.53	2.1	2.4	3.0	
VII	Low Fat	14.2	5.6	2.7	0.61	2.2	3.7	2.2	
X	High Fat	14.6	5.0	2.5	0.56	2.1	3.3	3.8	
III	High Fat	15.5	5.0	2.7	0.57	2.8	3.0	4.8	
IV	High Fat	15.8	5.0	3.0	0.74	2.8	3.6	4.2	
II	Home	15.8	7.5	3.2	0.64	2.3	1.4	3.7	
IX	Low Fat	16.2	6.3	3.1	0.68	2.9	4.7	2.1	
XII	High Fat	16.2	6.3	...	0.77	1.7	...	6.7	
VI	Low Fat	18.3	6.3	3.9	0.78	4.2	5.5	2.7	
VIII	Low Fat	23.5	8.8	4.8	1.11	3.3	6.7	3.2	
V	Home	23.7	5.6	4.6	1.00	1.8	10.2	3.7	

*The crude fiber and total dried weight of the diet was inserted here to show its relation to the composition of the feces. The total carbohydrate of feces was determined by difference which includes the crude fiber.

CHART D.
DISTRIBUTION OF FECAL SOLID.
SHOWING POOR CORRELATION BETWEEN
TOTAL FAT AND TOTAL SOLIDS IN FECES.



Because the role of basic ions, especially calcium, has been questioned in connection with the loss of fatty acids in feces, the total ash and calcium were studied here with very interesting results.

The calcium intake and loss in feces.--The calcium intake in grams was very slightly increased during the low fat periods, and a concomitant decrease occurred during the high fat periods. However, the amounts and per cents lost varied in all periods, as shown in Table XX, and were largely independent of the intakes. It has long been recognized that the calcium in feces is in large part an excretory product, hence this fecal calcium may not be expected to bear a direct relationship to the intake in well children. However, since the major excretion is through the feces, the per cent of the intake retained becomes a fairly representative index of the calcium balance. With this possible significance in mind, the per cent of the intake in feces was calculated on the basis of averages per composite period (Table XXII). These per cents were large, ranging from 50 to 100, without any apparent relation to the diet. In seeking an explanation for this, the calcium intake to fat intake ratios were calculated and charted against the per cent of fat retained, after the manner of Holt and Tidwell (Chart E). The ratios were found to be inversely proportional to the fat retention. This is in harmony with the results reported by the above mentioned authors. Nevertheless the data charted by them, showed that fat retention was little affected when the ratios were under 0.040, and, whereas there was a greater scattering of the per cents of fat retention at ratios from 0.040 to 0.060, there was by no means a consistent drop in retention, even on these high ratios, as found by these workers.

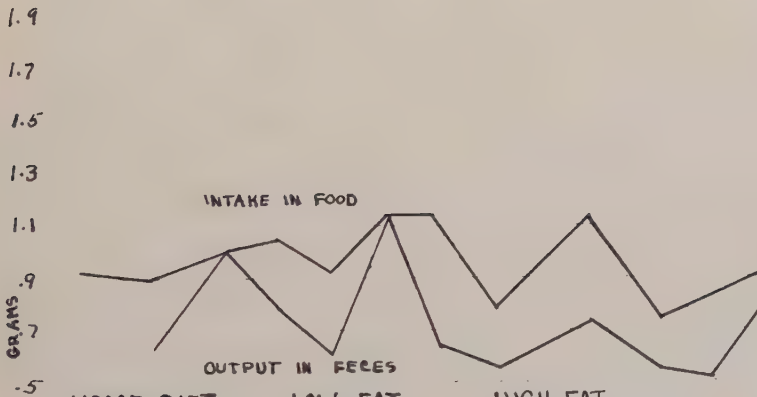
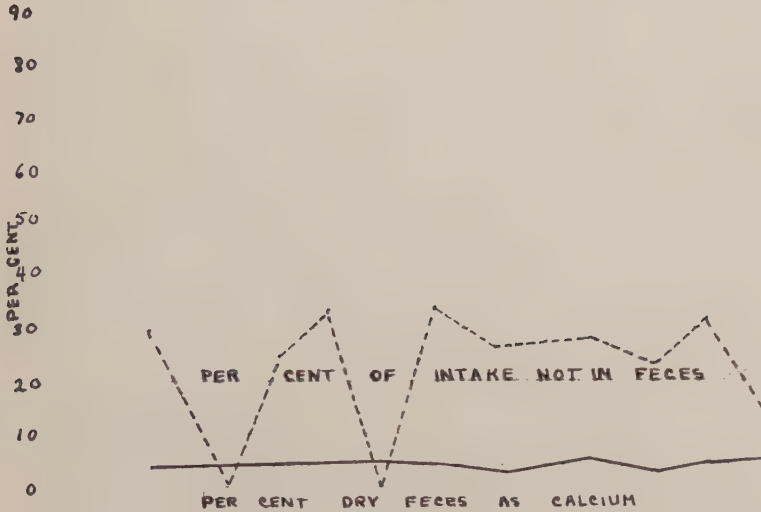
The ratios in the present study were, with one exception,

TABLE XXII

CALCIUM LOSS AS RELATED TO FAT INTAKES
(Average daily, and solids in feces)

Composite	Subject J						Subject T					
	Calcium			Per cent in Feces	Ratio Ca. Intake Fat Intake	Calcium Dietary Feces	Calcium			Per cent in Feces	Ratio Ca. Intake Fat Intake	Calcium Dietary Feces
	Intake	Feces	Differ-ence				Intake	Feces	Differ-ence			
	gm.	gm.	gm.	gm.	gm.	gm.	gm.					
Regular Home Diet												
I.....	0.90	0.57	0.33	63.4	0.016	0.054	0.93	0.54	0.39	69.6	0.012	0.041
II.....	0.98	0.62	0.36	63.3	0.015	0.045	0.92	0.64	0.28	100.0	0.012	0.041
V.....	0.04	0.64	0.40	61.6	0.018	0.052	1.00	1.00	0.00		0.013	0.042
Low Fat Diet												
VI.....	0.96	0.58	0.38	60.4	0.020	0.053	1.04	0.78	0.26	75.0	0.020	0.043
VII.....	0.99	0.97	0.02	98.0	0.022	0.044	0.93	0.61	0.32	65.6	0.020	0.043
VIII.....	1.84	0.89	0.91	50.5	0.050	0.057	1.12	1.11	0.01	99.1	0.025	0.047
IX.....	0.87	0.71	0.16	81.6	0.022	0.051	1.04	0.68	0.36	65.4	0.020	0.042
High Fat Diet												
XII.....	0.97	0.60	0.37	61.9	0.008	0.038	0.79	0.57	0.22	72.2	0.007	0.037
IV.....	0.82	0.58	0.26	68.3	0.009	0.038	1.04	0.74	0.30	71.2	0.008	0.047
X.....	0.79	0.70	0.09	88.6	0.006	0.036	0.74	0.56	0.18	75.7	0.005	0.039
XI.....	0.84	0.78	0.06	92.9	0.006	0.050	0.83	0.53	0.30	63.9	0.006	0.047
XII.....	0.81	0.58	0.23	71.6	0.006	0.043	0.91	0.77	0.14	84.6	0.006	0.048
Average Per Period												
Home.....	0.97	0.61	0.36	62.8	0.016	0.050	0.96	0.82	0.14	84.8	0.012	0.041
Low Fat.....	1.16	0.79	0.37	68.1	0.029	0.051	1.03	0.79	0.24	76.3	0.022	0.044
High Fat.....	0.85	0.64	0.20	76.7	0.006	0.041	0.86	0.63	0.23	73.3	0.006	0.044

CHART E. SUBJECT — J. DAILY CALCIUM INTAKE AND LOSS IN FECES. SHOWING THE STRIKING CORRELATION BETWEEN THE CALCIUM AND TOTAL SOLIDS IN FECES.

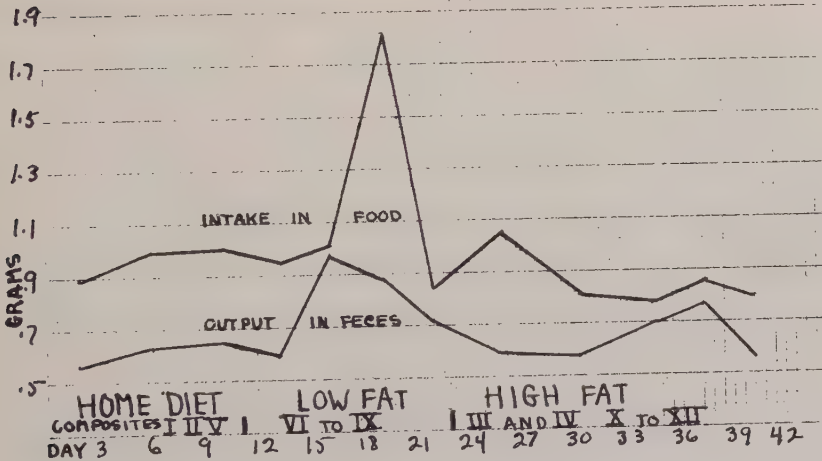
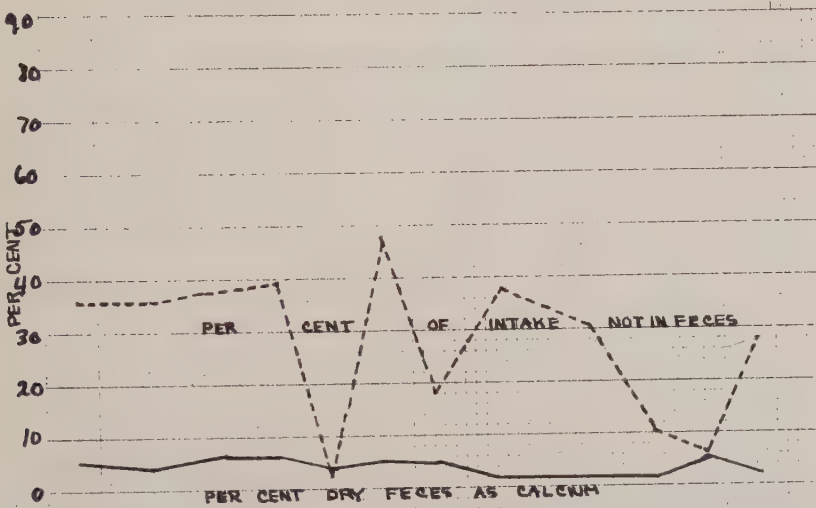


HOME DIET LOW FAT HIGH FAT
 COMPOSITES I II V I VI TO IX I III AND IV X TO XII
 DAY 3 6 9 12 15 18 21 24 27 30 33 36 39 42

0.025 or under (Table XXII). Hence, the agreement in the two studies is more apparent than real. Moreover, it has already been pointed out that the actual fat loss in feces was increased during the high fat intakes. When the amount of calcium in the feces was considered, it was found that the average calcium excretion was slightly lower during the high fat intakes. Thus, it has been impossible on the one hand to relate fat retention to calcium intake or, on the other, to show a correlation between fat and calcium loss in feces in this study. There seems to the author to be a high degree of probability that the improved fat retention bore a purely fortuitous relationship to the calcium fat intake ratio, as shown in Chart F.

Seeking further for an explanation of the extreme variation in the losses of calcium, it was found that the total solids of the feces and the total calcium lost showed close general correlation. When the calcium per gram of dried feces was calculated (Table XXII), it proved to be surprisingly constant and independent of the fat intake, the fat lost in the stool, the calcium intake, or the per cent of the calcium intake lost in stools. A survey of the literature for observations on this phenomenon brought to light the results and conclusions of Telfer in which he postulates a theory for the formation of feces by means of a calcium soap acting mechanically by incorporating in their mass various other excrements. Whether or not this is the correct explanation of the phenomenon, the present study quite conclusively demonstrates a direct relationship between the two quantities, namely, the total solid and the total calcium of feces.

CHART F. SUBJECT - T. DAILY CALCIUM INTAKE AND LOSS IN FECES. SHOWING THE STRIKING CORRELATION BETWEEN THE CALCIUM AND TOTAL SOLIDS IN FECES.



SUMMARY AND CONCLUSIONS

Studies of the reaction of the young child to fat in a freely selected diet, in which there were three levels for fat intake, have been carried through two continuous balances extending over a total of 42 days for each of two subjects. The average calories in the diet from fat were approximately 25, 40, and 60 per cent of the total for the low fat, regular home, and high fat diets respectively. Accepting the regular home diet series as the basis for comparisons, the following results were obtained.

There was a direct relationship between increased fat and increased total calories in the diet. When proper corrections were made for actual losses of energy in excreta this same relationship was found to be true for the net calories in the diet. This increase in available calories with increase in fat averaged 15.8 per cent for Subject T and 37.8 per cent for Subject J.

On the contrary, when fat in the diet was decreased there was first a drop in the caloric intake, then a return to normal by the end of the first week on the diets. There was no tendency at any time for the caloric value of the diets to increase beyond the regular home diet calories during the low fat ingestion.

The total calories ingested and the total "available calories" were found to be directly proportional to the intake. The coefficients of availability were nearly the same in all series, although the high fat intakes favored retention, being generally 1 to 2 per cent higher in all composites. This was related to improved coefficients of digestion of fat rather than to the coefficient of digestion for the protein and carbohydrate.

The total energy lost in feces averaged for both subjects 4.8, 4.8, and 5.6 calories per gram of dried feces for the regular home, low fat and high fat series respectively.

The percentage distribution of available calories during the regular home diet series was 15, 40, and 45 per cent for protein, fat, and carbohydrate respectively for both subjects, which was near the averages found in other studies, that is, 15 per cent as protein, 35 per cent as fat, and 50 per cent as carbohydrate calories. During the low fat diet series the per cent of total available calories from protein showed little change. During the high fat series there was an average drop to a low of 9.6 and 9.3 per cent of the total calories from protein for the two subjects. The fat calories during the three series averaged for both subjects 39.5 per cent, 26.5 per cent, and 61.6 per cent for the regular home, low fat, and high fat series respectively. The carbohydrate calories were increased during the low fat intakes to near 60 per cent of the total available calories, while during the high fat intakes this class of nutrient contributed approximately 30 per cent of the total calories.

The per cent of fat in feces was definitely related to the grams of fat ingested, but the total grams of fecal fat was influenced both by the fat intake and to a lesser degree by the total solids in the stool. The per cents of fat absorbed were not consistently as high on the low fat intakes, as during the regular home diet levels; while the per cents absorbed during the high fat intakes were improved over the regular home diet levels.

The per cent of the total fecal fat as neutral material varied in all periods, but in general the proportion was high during the periods of low excretion of total fecal fat. In other words, the grams of neutral fatty material were not decreased

appreciably during the low fat diets, but were increased definitely during the high fat series.

The total grams of fatty acids calculated as stearic acid were relatively higher than the neutral fraction in the regular home diet composites; in the low fat composites the fatty acids decreased rapidly, while the neutral fraction changed little; in the high fat series the neutral material was definitely increased, while the fatty acids remained near the regular home diet level of excretion.

The total grams of fat and protein absorbed were directly proportional to the intakes. The coefficients of digestion for the protein varied in all series and were independent of the fat in the diet or feces.

The grams of protein lost in excreta were directly proportional to the protein intake, but the per cent of the nitrogen intake that was retained was decreased during the low fat series and increased during the high fat series, especially during the latter days of the series.

The total excretion of acetone bodies varied directly with the fat in the diet, although there were fluctuations in all periods. In general, on the regular home and low fat diets, the total acetone bodies excreted per twenty-four hours varied from a trace to 60 milligrams, while on the high fat diets the excretion varied from 20 to 100 milligrams. The average excretions per series were 44.4, 32.8 and 57.3 milligrams for the regular home, low fat, and high fat series respectively for both subjects. The excretion during ten days when whooping cough was developing varied from 19.7 to 938.1 with an average of 228.1 milligrams.

The total dry weight of the feces was found to be unrelated to the fat in the diet. Likewise neither the crude fiber nor the

total dry weight of the diet bore any consistent relation to the total solids of the feces. There was in general a direct proportion between the total solids in the feces and the amounts of calcium and total ash contained therein.

The calcium loss was related to the total solids in the feces and was independent of the fat or calcium intake.

The data presented herein seem to the author to justify the following conclusions: (1) that generally children have a tolerance for fat equal to or beyond that most frequently found in freely selected home diets; (2) that in so far as excellent fat, nitrogen, and energy retention, and the attainment of good general health and happiness are concerned, the levels of fat intake may vary from 25 to 65 per cent of the total caloric intake; (3) that there is a direct upward trend in the excretion of total acetone bodies per twenty-four hours as the fat in the diet is increased even when the fatty-acid to glucose ratios are as low as 1.0:4.8 to 1.0:1.1; (4) that ketosis, as usually defined, does not occur in the "well" child but may occur in the "ill" child on the above described levels of fat intake.

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